A PRACTICE OF
GENERAL ANÆSTHESIA
FOR NEUROSURGERY

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by

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FOREWORD

In this monograph the authors describe their technique of anæsthesia in neurosurgical cases This has been developed in the course of a considerable experience of the differing types of case admitted to the Department of Neurological Surgery in a general hospital Much thought has been given, not only to the special technical problems which arise in connection with such patients but also to the more fundamental ones of intracranial pressure and the methods by which it may be reduced The place of vascular hypotension and hypo thermia in operations upon the brain receives careful consideration This description of a carefully planned and efficient technique which reduces risks to the patient s life and function to a minimum should be of value to a large group of anæsthetists—particularly to those new to the field of neurosurgical anæsthesia or those called upon but infrequently to anæsthetize neurosurgical patients

The pages do more than explain a technique they reveal an attitude of mind In the past neurosurgical anæsthesia has appeared unattractive to some and was avoided for what was considered to be more rewarding work the frequently long and sometimes dangerous operations no doubt partly explain this attitude The present authors clearly regard themselves as being part of the neurosurgical team their interest in the patient commencing before his arrival in the anæsthetic room and being maintained after he leaves the operating room Pre operative assessment supportive treatment during surgery and assistance with post operative care have been accepted as among the anæsthetists responsibilities The value of such team work on the frontiers of surgery cannot be overestimated

Since this small book fills a gap in the literature of anæsthesia and illustrates the widened field of activity of the modern anæsthetist I believe that it will be found to be of both interest and value

J E A O CONNELL

IN MEMORY OF
BRIAN RAIT SMITH

Printed in Great Britain

PREFACE

Our purpose in this monograph is to describe in detail general anæsthetic techniques that we have found simple and efficient in neurosurgery and to mention the work of others in this field

Experience gained from clinical teaching and from discussions with post graduate students has convinced us that neurosurgical cases are particularly worrying to anæsthetists unfamiliar with them We trust therefore that this writing based on lectures given by one of us for the course on anæsthetics at the Royal College of Surgeons will be of particular help to these anæsthetists and others who do not work in neurosurgical units We hope that it will also fill the gap that many examination candidates have found in the literature and interest all thoughtful anæsthetists who realize that there are many problems in this branch of anæsthesia

We have not included local anæsthetic techniques as these are so admirably described in Local Analgesia Head and Neck by Sir Robert Macintosh and Mary Ostlere (E and S Livingstone Ltd, Edinburgh and London)

We are grateful to Dr C Langton Hewer and Mr J E A O Connell for their invaluable criticism and advice in the preparation of the manuscript and for the knowledge we have gained from them in discussions over the years

We are indebted to Mr N K Harrison and the Photographic Department of St Bartholomew s Hospital for their enthusiastic help in the preparation of the photographs and to Dr A M Hall Smith for the drawings

We also wish to thank Dr G du Boulay for the radiographs Dr B G Wells for the electrocardiograms in Chap 6 Mr J Andrew for advising us on points of neurosurgical technique Miss M Thomas for her help with the details of nursing procedure in Chap 11 and those authors and publishers who have given permission for the inclusion of various illustrations and tables

Finally we wish to express our gratitude to Mrs Gwen Seager who prepared the typescript and calmly brought order out of chaos

ROBERT I W BALLANTINE
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London E C 1

Chapter 1

GENERAL CONSIDERATIONS AND PROBLEMS

THE operation of trephining was performed in the late Stone Age, possibly for the relief of headache Davison[1] suggests that it is more likely to have been for the evacuation of obstinate demons or that it was a purely magical rite, and tells us that the removed discs of bone were often used as amulets

Neurosurgery started its development as a specialized branch towards the end of the nineteenth century Douglas Guthrie[2] describes how this began in London in 1884 when Sir Rickman Godlee was the first to remove successfully a brain tumour He continues the history by recording that a brain abscess was drained by Arthur Barker in 1886 closely followed by Sir William Macewen who performed a series of twenty four of these operations with only one failure Sir Victor Horsley in 1887 removed an accurately localized tumour of the spinal cord and performed craniotomies under general anæsthesia with chloroform Sir Percy Sargent developed his technique the patients being anæsthetized by the insufflation of an air–ether mixture[3] In America it was Walter Dandy and Harvey Cushing (1869 to 1939) who did so much for the subject Much of the early progress in neurosurgical anæsthesia was due to the work of Dr Z Mennell Since then the advances in both surgery and anæsthesia have been considerable so that today cerebral aneurysms meningiomata acoustic neurinomata and many other previously fatal conditions of the brain and spinal cord can be successfully treated

Gradually as anæsthetists have gained increasing control of the airway the respiration the circulation and the body temperature and as pharmacologists have introduced non explosive drugs of low toxicity the demand for general anæsthesia and for anæsthetists experienced in this branch has increased In spite of this neuro surgical anæsthesia has received less attention than some other branches of the specialty and the number of neurosurgical centres

CONTENTS

The Problems

These will be mentioned briefly here and then discussed fully in subsequent chapters

1 Intracranial pressure

There is a pre existing raised intracranial pressure in many cases requiring craniotomy This raised pressure may result in alterations in the blood pressure, pulse, respiration and level of consciousness

2 General condition

The patients are sometimes extremely ill and are therefore poor operative risks

3 Hæmorrhage

The danger of severe hæmorrhage is present in cases of aneurysm vascular tumour and arteriovenous malformation Venous oozing may be troublesome in any cranial or spinal operation If anæsthesia is bad and the position of the patient incorrect oozing may increase so much that the operation becomes almost impossible

4 Cerebral ischæmia

Some ischæmia will follow vascular spasm or elective occlusion of cerebral vessels It is mainly the problem of the anæsthetist to protect the brain tissue from the effects of this

5 Head injuries

These present a variety of problems in many of which the anæsthetist with his specialized knowledge of respiratory and cardiovascular physiology will be concerned not only in the theatre but during transport and in the wards

6 The airway

Flexion and rotation of the head are usually necessitated by the surgical approach and increase the problem of maintaining a perfect airway

has been relatively small The result is that students have been hard pressed to find information on the subject and have not been helped by those who think that little information is required

There are some who believe that neurosurgical anæsthesia consists in passing an endotracheal tube and then spending a day lost in philosophical thought! By this attitude they show their ignorance of the whole subject In no other branch of surgery can a careless anæsthetic impede the surgeon or imperil the patient more easily It is a common misconception that neurosurgical cases do not present any anæsthetic problems yet as Hunter[4] has pointed out the responsibility of the neurosurgical anæsthetist is often heavier than that of his colleagues in other fields Furness[5] echoes this when she describes neurosurgical anæsthesia as the most humbling of all Anyone who has taken an interest in the subject will agree

In many of these cases the vital centres are directly affected by a raised intracranial pressure before operation or anæsthesia begins Intracranial pressure will usually rise after induction and medullary function may be further disturbed by surgical manipulations The operations are long and patients often seriously ill Complete co operation and mutual confidence between the anæsthetist and surgeon are essential The surgeon must be informed immediately of any major change in the patient s condition The signs of a rising intracranial pressure may become evident and demand surgical intervention Similarly an alteration in the clinical picture may be due to retraction or dissection and a timely warning from the anæsthetist may help in avoiding permanent damage, or post operative œdema of nervous tissue

The anæsthetist must have confidence in his method He must be sure that the surgical picture is not confused by cardiovascular or respiratory effects of drug origin For this reason the anæsthetic should be simple and the minimum of depressant and paralysing drugs used Patient and constant vigilance is required at all times and strict attention to the smallest details of technique will be repaid by improved operating conditions It is intended in this monograph to stress these simple fundamental points for it is these that make the difference between a good and a bad anæsthetic

10 Diathermy

The use of diathermy requires non explosive anæsthetic agents

It will be evident that the intracranial and venous pressure are of primary importance and require closer study

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[5] FURNESS D N (1957) *Brit J Anæsth*, 29, 415

7 Posture

The sitting prone lateral and steep reverse Trendelenburg positions, which aid the surgeon may add to the anæsthetist s problems

8 Inaccessibility

It is difficult to alter the position of the endotracheal tube once the operation is in progress and the anæsthetic apparatus must be

FIG 1 This drawing shows the tent used in some neurosurgical units to facilitate access to the patient under the surgical towels

well clear of the operation site To improve access some neuro surgical teams use a form of tent under which the anæsthetist can approach the patient s head without disturbing the towels or the progress of the operation (Fig 1)

9 Time

The operations may take many hours

10 Diathermy

The use of diathermy requires non explosive anaesthetic agents

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Chapter 2

INTRACRANIAL PRESSURE

WHEN considering the relationship of intracranial pressure to anæsthesia, injury or disease, it is essential that the anæsthetist should become accustomed to relating the patient's various responses and his own actions to one fundamental fact, that the nervous tissue comprising the brain and cranial nerves and the membranes which surround them are enclosed in an inexpansible box together with a quantity of fluid in the form of blood, C.S.F. and extra cellular fluid. He must realize that any uncompensated quantitative change or alteration in position of these components relative to one another will adversely affect normal function. This concept of the invariability of the volume of the intracranial contents as a result of the rigidity of the cranial boundaries was originated by Alexander Monro (1783) and elaborated by Kellie (1824) and is known as the Monro Kellie doctrine.

Before considering the changes brought about by abnormal function it is essential to have a thorough knowledge of the normal C.S.F. formation, circulation and absorption, and of the mechanism by which C.S.F. pressure, and to some extent normal intracranial pressure, is maintained.

Cerebrospinal fluid

This is a clear, colourless, slightly alkaline fluid contained within the subarachnoid spaces and the ventricular system. In normal conditions there are 100 to 150 ml. of fluid having a specific gravity at body temperature of 1.003 relative to water at 4° C.[1]

The main constituents are—

Cells: 1 to 3 lymphocytes per cu. mm.
Chlorides (as NaCl): 700 to 760 milligrams per 100 ml.
Protein (total): 20 to 40 milligrams per 100 ml.
  Globulin test: negative
Sugar: 45 to 100 milligrams per 100 ml.
  Qualitative test: positive
Urea: 10 to 40 milligrams per 100 ml.

It is interesting to note that Leonardo da Vinci demonstrated the ventricular system over 400 years ago Three hundred years later Magendie pointed out the connections between the ventricles and subarachnoid space and hence the course of the C S F circulation Cushing was able to confirm earlier work that the C S F was formed by the choroid plexuses when he saw fluid coming from these at operation

Formation

The precise method of C S F formation is still open to some doubt It would appear that it is neither a pure process of filtration from the capillaries in the plexuses nor is it a simple process of secretion The cells of the plexus 'actively regulate the transfer of ions and other crystalloids so as to maintain a characteristic electrolyte structure in the C S F which differs from that of the plasma -Whatever the exact method of formation may be, it is known that the majority of the fluid originates from the large choroid plexuses found in the lateral ventricles

Circulation

The fluid passes from the lateral ventricles through the foramina of Munro to the third ventricle then via the aqueduct of Sylvius to the fourth ventricle and out to the subarachnoid space via the central foramen of Magendie and the two lateral foramina of Luschka Once in the subarachnoid space the C S F passes round over the cerebellum and brain stem towards the gap in the tentorium cerebelli through which it passes to reach the inferior surface of the cerebrum It then passes over the lateral aspect of the hemispheres towards the superior sagittal sinus where most of it is absorbed through the arachnoid villi

Some of the fluid passes along the sheaths which surround the cranial nerves and some into the spinal subarachnoid space where about one fifth of the absorption takes place [9]

The circulation is thought by some to depend upon a balance between the factors regulating production and absorption but may be activated by the variation in intracranial pressure produced by

inspiration and cardiac systole O Connell[3] has shown that respiratory and cardiac activity alter intracranial pressure by 80 mm of fluid every few seconds It has also been shown that in the erect *position, at any given moment the pressure at the vertex is lower* than at the base of the skull

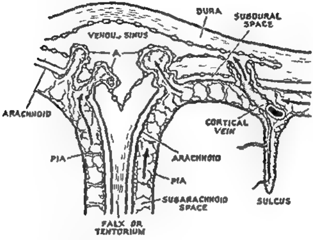

FIG 2 Diagram to show relations of Pia arachnoid *Arachnoid Villi and Cortical Veins to Dural Sinuses* Note the blood vessel coming from the brain substance surrounded by a continuation of the subarachnoid space The arrows show the direction of flow of the cerebrospinal fluid A = arachnoid villi (Modified from Weed) (H Cushing *Intracranial Physiology and Surgery* 1926) (From Wright S (1952) *Applied Physiology* 9th edition Reproduced by courtesy of Oxford University Press)

Absorption

This is from the subarachnoid space by a process of filtration and osmosis largely through the arachnoid villi into the dural sinuses and to a lesser extent via the smaller cerebral and spinal veins (Fig 2)

Intracranial Pressure

This is measured in the horizontal position with the spine and external occipital protuberance in the same line It is usually

between 60 and 150 mm of C S F These normal values are maintained partly by a regulation of the production and absorption of fluid, and partly by what has been described as an arterial and venous vascular factor It is suggested by O Connell[4] that the cerebral veins play a large part in the maintenance of normal intracranial pressure It is suggested that as the C S F pressure within the cranium falls when a previously horizontal patient is tilted head up, so the veins dilate and permit the passage of C S F from the cranium into the spinal cavities If the head is lowered the C S F pressure in the cranium will rise The veins then diminish in size to make room for the normal volume of C S F in the head in this position

Variations in intracranial pressure

1 Physiological changes These are continually occurring in association with cardiac and respiratory activities and postural changes

2 Abnormal changes

A Decrease in Pressure

(i) Blood loss and dehydration

(ii) Post operative following removal of space occupying lesions (e g sub dural hæmatoma)

(iii) Post lumbar puncture and spinal anæsthesia probably due to seepage of fluid

(iv) Various neurological disorders

B Increase in Pressure

(i) Decreased skull volume due to bony tumour or craniostenosis

(ii) Increased skull content from Tumour or abscess Hæmatoma Hydrocephalus Venous obstruction Cerebral œdema and anoxia (these may be complementary)

Intracranial hypotension is recognized as a clinical syndrome[5] but is unlikely to cause the anæsthetist any great concern However following the removal of extra- or sub dural hæmatomata the resulting intracranial hypotension may be treated by lowering the head of the table and transfusion with hypotonic saline

Increased intracranial pressure is far more common and usually more serious In the early stages of a rising intracranial pressure C S F is forced out of the ventricular system to make more room for whatever is causing the rise As this progresses the gyri and sulci become compressed and flattened This same process of pressure and flattening occurs in the veins The veins in the locality of a space occupying lesion become compressed with engorgement of the territory which they drain In the optic discs this will cause papilloedema which is the same as oedema of the brain itself and arises from the same cause Associated with the raised intracranial pressure may be the characteristic clinical picture of headache vomiting altered consciousness epilepsy and a variety of other neurological signs and symptoms

The later stages of raised intracranial pressure rather depend on the siting of the tumour relative to the tentorium Supratentorial tumours naturally tend to raise the pressure above this dural fold The anterior free border of this structure surrounds the mid brain but is separated from it by the subarachnoid cistern through which passes the oculomotor nerve As the supratentorial pressure rises the uncus tends to be forced down between the mid brain and the edge of the tentorium so stretching and impairing the function of this nerve If the paralysis is complete there will be ptosis external strabismus and pupillary dilatation Usually however the paralysis is incomplete and dilatation of the pupil occurs alone More important is the effect of the herniation of the brain stem with disturbance of consciousness

When the lesion causing the raised pressure is below the tentorium brain stem damage often accompanied by restriction of the normal circulation of C S F is common Damage to the pons medulla and hypothalamus may be direct depending on the siting of the tumour or from interference with the normal vascular supply from pressure distortion of blood vessels This distortion may also be responsible for impeding C S F flow through the foramina of Magendie and Luschka or from the posterior fossa via the tentorial opening to the middle cranial fossa Wherever the block may be raised intra cranial pressure is further aggravated by rising C S F pressure and a vicious circle is established If allowed to continue the cerebellum

and medulla are gradually forced into the foramen magnum with the result that further restriction of the blood supply occurs The resulting anæmia at first stimulates the vaso motor centre in the floor of the fourth ventricle, and so initiates a rise in the systemic blood pressure in an attempt to force blood through the cerebral vessels Cushing described this as part of a series of events occurring with rising posterior fossa pressure the so called ' Cushing s triad As the systolic pressure rises the diastolic pressure falls due to diminishing tone in the arterioles At the same time stimulation of the vagal centre produces a slowing of the pulse through normal vagal overaction Respiratory irregularities add to an already desperate situation As medullary ischæmia progresses the respir atory centre is depressed and respiration slows becomes shallow and finally ceases The reflex rise in systemic blood pressure may be sufficient to restore circulation temporarily to the respiratory centre and thus re establish spontaneous respiration During this state a series of normal respiratory movements followed by a pause may occur but more commonly respiration at first shallow gradually increases in depth as the blood pressure rises At the same time the respiratory centre is stimulated by carbon dioxide which has accumulated during the period of apnœa When the blood pressure falls again and the carbon dioxide level falls so the tidal volume decreases once more in a periodic manner, the so called periodic or Cheyne Stokes breathing This series of events continues until the cardiovascular centre can no longer respond to oxygen lack and fails The blood pressure then falls rapidly to the region of 40 mm Hg respiration ceases for good and death rapidly ensues

The symptoms and signs of raised intracranial pressure will obviously vary from mild headache (following minor injuries) with a slowly developing mass to Cushing s triad from a rapidly expand ing hæmatoma Its degree is not necessarily related to the size of the tumour or abscess but often to the amount of œdema that surrounds it Nervous tissue appears to be particularly liable to the formation of this additional extracellular fluid A very small tumour may produce an enormous area of œdema around it and thus all the effects of a very high intracranial pressure

Cerebral œdema

The formation of cerebral œdema is obviously related to the initial pathology but may be due to any of the following—

1 Inflammation
2 Cerebral tumour
3 Cerebral trauma with or without fractured skull
4 Cerebral hypoxia
5 Venous obstruction

1 Inflammation—cerebral abscess There is excessive exudation into the tissue spaces of a protein rich fluid The water absorbing power of the extracellular spaces is thus increased at the expense of the surrounding capillaries with the result that still further fluid passes out of the cellular and into the tissue spaces

2 Cerebral tumour These produce a surrounding œdema in two ways—

(*a*) Small veins are compressed so that there is an increased hydrostatic pressure to filter fluid out into the tissue spaces

(*b*) It has been shown that tumour cells produce toxic metabolites which increase capillary permeability in the immediate neighbour hood thus allowing transudation of tissue fluid into the tissue spaces

3 Cerebral injury Following severe head injuries contused and traumatized brain tissue rapidly becomes œdematous, as does tissue elsewhere in the body Unconsciousness is common and is often accompanied by some degree of respiratory obstruction In addition as Maciver[6] and his colleagues have said severe damage to the vital areas of brain tissue produced by distortion and impaction may seriously depress the respiratory centre control by direct injury or by interference with the vascular supply In either case cerebral anoxia and respiratory acidosis occur and further embarrass the already contused brain

4 Cerebral hypoxia Hypoxia is tolerated in widely different amounts by the various body tissues Thus a limb may be without oxygen for several hours and still recover whilst brain tissue will die if it is deprived of its oxygen supply for longer than three minutes at normal temperatures The brain is equally susceptible to smaller degrees of oxygen lack and therefore may be affected to a greater or

lesser extent by a large number of clinical conditions associated with this[7] (Fig 3)

ANOXIA OR HYPOXIA

ANOXIC	ANÆMIC	STAGNANT	HISTOTOXIC
During Operation— Low Oxygen / mixture Badly administered N_2O Acute or Chronic respiratory obstruction e g Laryngeal spasm Inhalation of vomit Complications during thoracic operations etc Prolonged respiratory arrest Severe bronchospasm *Post operative—* Respiratory obstruction Massive collapse of lung Inhalation of blood vomit Partial curarization	Chronic anæmia plus Another factor Hæmorrhage— Traumatic Operative Post operative Carbon monoxide poisoning	Cardiac arrest Shock— Traumatic Surgical Post operative Hypotension from too prolonged or drastic use of 1 Arteriotomy 2 Hexamethonium 3 High spinal	Anæsthetic overdose

Other conditions—
Anoxic attack in Fallot s tetrad
Acute respiratory obstruction
e g Laryngeal œdema
Carc of larynx
Hæm into thyroid cyst etc
Pneumonia bronchopneumonia
Paralytic poliomyelitis
Asphyxia neonatorum following fœtal distress
Barbiturate poisoning

HYPOXIC CEREBRAL DAMAGE
and
? CEREBRAL ŒDEMA

FIG 3 Examples of clinical conditions which may lead to cerebral hypoxia and œdema (Reproduced by courtesy of Argent D E and Cope D H P (1956) *Brit med J* 1 593)

Oxygen lack from whatever cause adversely affects cerebral functions The blood pressure is raised by direct and reflex stimulation of the vasomotor centre Blood is diverted from the less essential structures to the heart and brain the capillaries themselves

dilate, and with actual damage to their walls permeability is increased with the production of cerebral œdema

5 **Venous obstruction** The effect of local compression of veins and the production of œdema has already been mentioned in relation to papillœdema

Venous Pressure

From what has been said it will be obvious how much anæsthetic techniques and drugs may influence intracranial pressure and surgery It is not difficult to appreciate how a patient with a high intracranial pressure may be brought to the verge of immediate death from medullary anæmia, by coughing during induction The key to much of this lies in venous pressure and venous return to the heart

It will be remembered that absorption of C S F occurs through a process of filtration and osmosis from the subarachnoid space into the large venous sinuses and to a lesser extent into the smaller cerebral and spinal veins Whatever the route may be these sinuses and veins are in direct communication with the large venous trunks returning blood to the right side of the heart As they have little muscular tissue in their walls and no valves pressure changes in one section of the venous return are quickly registered elsewhere along the venous pathway For example jugular compression performed during a craniotomy produces an immediate distension of the cerebral veins and bulging of cerebral tissue

Under normal circumstances the following are responsible for maintaining the venous return—

1 Muscle contraction

2 Capillary pressure tone and the influence of the vasomotor centre

3 The thoracic pump action

4 Gravity

So far as neurosurgical anæsthesia is concerned the last two are of particular importance

Thoracic pump

During inspiration there is a negative pressure produced in the thorax which draws blood down the great veins towards the heart There is a decrease in intracranial blood volume during inspiration

and diastole and an increase during expiration and systole When respiratory obstruction develops the normal intrathoracic pressure changes of the respiratory cycle are altered A forced expiration whether from respiratory obstruction, coughing or straining raises the venous pressure considerably as the increased intrathoracic pressure compresses the venæ cavæ and prevents venous return into the chest There is a reflux of blood into the brain

At the same time, a rise of pressure occurs in the vertebral venous plexus This is transmitted from the inferior vena cava via the abdominal veins and results from the increased intra abdominal pressure that follows the use of the abdominal muscles in forced expiration The engorgement of the vertebral plexus will also contribute to the rise in intracranial venous pressure It will be seen later (Chapter 8) how similar abdominal compression in the prone position may interfere with spinal surgery by causing severe venous oozing

Following even a short bout of coughing or respiratory obstruc tion, cerebral engorgement persists for some time and the brain bulk is increased In addition to this and the increased venous oozing, rupture of veins in the brain stem may occur

Inadequate respiratory activity and a reduction in the efficiency of the thoracic pump action will also give rise to congestion [7] Simul taneously anoxia and carbon dioxide excess by dilating capillaries will increase congestion [6] The cerebral blood flow is increased by 75% from the inhalation of 5% to 7% carbon dioxide [8]

Gravity

Gravity helps considerably in encouraging an adequate venous drainage from the skull and the importance of positioning neuro surgical patients correctly on the operating table cannot be over emphasized

It will be realized from these particular and other more common problems that good anæsthesia requires that the following must be avoided—

1 Respiratory obstruction

2 Reflex respiratory effects such as coughing straining and breath holding

3 Inadequate respiratory activity from depressing and paralysing drugs

4 Anoxia and carbon dioxide accumulation

5 Incorrect posture

6 Increased respiratory resistance from anæsthetic apparatus

7 Deep anæsthesia and the use of toxic explosive drugs or those that raise intracranial pressure

8 Delay in replacing blood loss

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Chapter 3

PREMEDICATION AND ANÆSTHETIC TECHNIQUE

THERE is no method that will solve all the problems and it is a simple matter to criticize each one The technique to be described here is probably no exception but it has several features to recommend it—

(a) It works well in practice, giving good operating conditions

(b) It can be used with only slight modification in every neuro surgical operation and investigation

(c) It is simple

(d) It may be combined with hypotensive and hypothermic procedures

(e) It has stood the test of time

Premedication

Heavy sedation must be avoided in the following—

(a) All patients with a raised intracranial pressure (This includes craniotomies ventriculographies and pneumoencephalographies)

(b) Head injuries

(c) Patients to be operated upon in the prone sitting or steep reverse Trendelenburg position

The reasons are—

(a) The patient s level of consciousness may be altered before premedication with respiratory abnormalities already present or likely to occur The opium derivatives and barbiturates will further depress respiration and drowsiness may become irreversible coma [1]

(b) Depressant drugs in old and ill patients in the prone or sitting position increase the risk of postural hypotension and make them more sensitive to anæsthetic agents

(c) After craniotomies it is important to have the patient awake and moving in the theatre A brief examination of his general and central nervous systems can then be made This will serve as a useful standard for the assessment of his subsequent progress

particularly in relation to post operative intracranial hæmorrhage and œdema

Atropine

In the above cases atropine is given alone 45 minutes before *induction, the dose being*—

Adults gr $\frac{1}{100}$ (0 6 mg)
Children over 5 years gr $\frac{1}{100}$ (0 6 mg)
between 2 and 5 years gr $\frac{1}{150}$ (0 4 mg)
under 2 years gr $\frac{1}{200}$ (0 3 mg)

Scopolamine

Scopolamine (hyoscine) alone has also been used successfully for a number of years in a dose of gr $\frac{1}{150}$ (0 4 mg) between the ages of 10 and 65 years It is a depressant of the central nervous system which is a disadvantage in those already stuporose but useful in the patient who is alert pre operatively It was preferred to atropine as at one time it was thought not to increase the pulse rate in therapeutic doses It has since been shown that gr $\frac{1}{100}$ (0 6 mg) subcutaneously will usually cause a definite rise although later the pulse rate may fall below the pre injection level

In other cases standard premedication is used such as—

Adults Omnopon gr $\frac{1}{3}$ (20 mg) } 1½ hours pre operatively
scopolamine gr $\frac{1}{150}$ (0 4 mg) }

If there is a history of asthma or evidence of bronchospasm on examination before operation then pethidine 100 mg should replace Omnopon and ephedrine gr $\frac{1}{4}$–1½ (16–100 mg) or an antihistamine such as promethazine hydrochloride (Phenergan) 25 mg be incor porated in the premedication Pre operative preparation with *cholinetheophyllinate (Choledyl) 100–200 mg* four times *daily may* be used with advantage in the asthmatic patient

Children Omnopon } 1 minim of the 1 ml ampoule (containing Omno
scopolamine } pon gr $\frac{1}{3}$ and scopolamine gr $\frac{1}{150}$) is given for each year of age

That is a child of 8 years would receive 8 minims of Omnopon gr $\frac{1}{6}$ (10 mg) and scopolamine gr $\frac{1}{300}$ (0 2 mg) When doses of

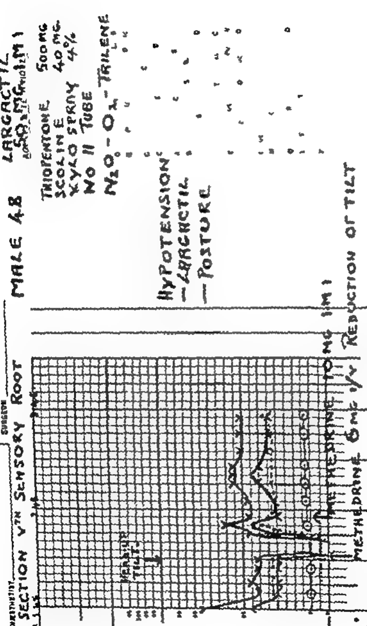


FIG 4 Section of Vth sensory root in male of 48 years Anæsthetic chart showing postural hypotension probably associated with chlorpromazine premedication

4 minims or less of the mixture are given atropine gr $\frac{1}{200}$ (0 3 mg) must be added

Alternatively, sodium propyl methyl carbinyl allyl barbiturate (Seconal) gr $\frac{1}{2}$ (30 mg) per stone of body weight with gr 3 (200 mg) as the maximum dose is given by mouth $1\frac{1}{2}$ hours pre operatively with atropine by injection one hour later The advantage of this barbiturate premedication is that children will often arrive in the anæsthetic room asleep, the disadvantage that restlessness may accompany recovery With Omnopon the child will not be asleep but will usually be co operative

The very nervous child may be given rectal sodium thiopentone, provided of course that there is no raised intracranial pressure with altered level of consciousness The dose is 1 g for each 50 lb of body weight (20 mg per lb) dissolved in 20–40 ml of water with a maximum dose of 1 5 g and is preceded by atropine

For ventriculography or other investigations under local anæs thesia phenobarbitone gr 3 (200 mg) is given $1\frac{1}{2}$ hours before operation in adults

The phenothiazine derivatives have been tried for premedication It was found that with chlorpromazine tachycardia, postural hypo tension (Fig 4) and prolonged recovery were a disadvantage Similarly after quite small doses of promethazine, drowsiness complicated the post operative picture Hunter[3] has rejected these two drugs for similar reasons but in a preliminary trial has found the combination of pecazine (Pacatal) with phenobarbitone encouraging

The use of these drugs in hypothermia will be discussed later as well as the preparation before hypophysectomy (See Chapters 6 and 7)

Anæsthetic Technique

First the procedure adopted in the majority of cases will be described and then discussed together with alternatives

Induction

If the intracranial pressure is known to be high the head end of the trolley is raised before induction Some anæsthetists recommend

the use of intravenous 50% sucrose or other hypertonic solution prior to induction in these cases

The minimum amount of sodium thiopentone in 5% solution is injected intravenously It is better to give subsequent additional doses than too much at first The drug is given slowly, and when it is certain that no apnœa has resulted 25–40 mg of suxamethonium is injected through the same needle The lungs are inflated with

FIG 5 Pharyngeal spray (Frank A Rogers)

oxygen six to eight times laryngoscopy performed and the trachea and glottis sprayed with not more than 5 ml of 4% lignocaine hydrochloride (Xylocaine) using the Rogers pharyngeal spray (Fig 5) The largest flexometallic tube of suitable length and with the bevel removed[1] is passed gently and connected via a short catheter mount to the semi-closed circuit of a Boyles machine The lungs are inflated with nitrous oxide 7 litres per minute and oxygen 3 litres per minute until spontaneous respiration returns The Magill expiratory valve is then fully opened and trichlorethylene added with the lever in the half to three quarters on position (0 5 to 1%) the plunger never being used An airway is inserted and the tube *very firmly* strapped with 1 in strapping and 3 in Elastoplast An efficient arrangement is shown in Fig 6

A Mitchell needle is inserted into a vein on the dorsum of one foot and in all craniotomies, laminectomies for spinal tumour and other major cases an intravenous saline drip into the other The blood pressure apparatus and electrocardiographic leads are applied After 10 to 15 minutes the patient should be settled The re breathing attachment is then removed from the machine and the quality of the airway auscultated through this while the patient's

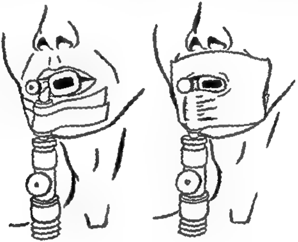


Fig 6 Endotracheal tube fixation

head is flexed and rotated Not until the airway remains perfect with the head fully flexed and with no coughing or straining is the patient transferred to the theatre

Maintenance

Great care is taken to position the patient correctly and more details of this will be given later but in every case the operation site is raised above heart level Before the towels are in position and the patient's head obscured the airway is again checked and the chest movements observed The operation is never begun until the airway is perfect and the chest lifting freely with no evidence of straining

Nitrous oxide oxygen and trichlorethylene are continued whilst the surgeon infiltrates the skin and subcutaneous tissues with

adrenaline 1/500,000 in normal saline and 8 to 10 minutes later makes the skin incision Trichlorethylene is continued until the bone flap has been raised and it may then be possible to keep the patient settled in the intracranial cases with nitrous oxide and oxygen alone, unless surgical stimulation is too intense The brain *itself is insensitive but there are certain sensitive intracerebral* areas—

(*a*) The basal dura

(*b*) The area around the middle meningeal artery

(*c*) The nervus spinosus

(*d*) The trigeminal ganglion

If alteration in the respiratory pattern occurs during nitrous oxide and oxygen anæsthesia alone it will probably be that the patient is too lightly anæsthetized and trichlorethylene must be added In practice there is no harm in allowing a trace of trichlorethylene during long operations provided it is turned off near the end to allow rapid recovery A very small amount of the drug will prevent the patient from reacting to the endotracheal tube and ensure quiet operating conditions

If tachypnœa develops then pethidine hydrochloride in doses of 10 mg at a time may be given intravenously provided there is no danger of respiratory depression from surgical or pressure effects, and provided 5 to 10 minutes is allowed between each dose to assess its effect

The blood pressure pulse and respiration rates are charted every 5 to 10 minutes and continuous electrocardiographic monitoring is an advantage if a machine is available Blood is already cross-matched for every major case and given as required to replace blood lost If unexpected hæmorrhage does occur in a neurosurgical case it may be severe and require replacement rapidly (Fig 7)

Extubation

When the bandages are in place a well greased soft rubber catheter is passed down the endotracheal tube and suction then applied if there is evidence of secretion This is done as gently as possible to minimize stimulation and coughing with the consequent rise in intracranial pressure and danger of initiating post operative bleeding

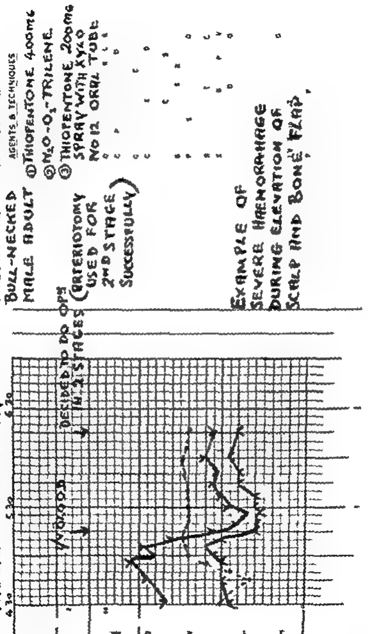


FIG 7 Anæsthetic chart showing the effects of hæmorrhage This operation was performed in two stages using a hypotensive technique for the second stage

The mouth and pharynx are cleared of any mucus and the tube removed

The patient is lifted into bed and his airway, general and neuro logical condition checked before he is handed over to the nursing staff It has been stressed that the obligation for ensuring competent supervision of the patient rests entirely with the anæsthetist,[5] and this is particularly so in neurosurgical cases A period of respiratory obstruction post operatively with its attendant anoxia carbon dioxide accumulation and rise in intracranial pressure may very easily have fatal results

Children

Most children over the age of 7 years are anæsthetized in the same way as adults For infants and younger children induction is with ethylchloride and open ether or nitrous oxide oxygen and diethyl ether given until intubation can be performed Ayre s T-piece[6] is attached and once the child is settled the diethyl ether is turned off and the trichlorethylene used for maintenance The usual practice is to have the trichlorethylene on for 5 minutes and then off for 5 to 10 minutes and so on The use of halothane (Fluothane) in children is discussed later, for it seems likely that this will replace trichlorethylene as the agent of choice in children undergoing neuro surgical operations

The following table reproduced by courtesy of Ayre[6] is a useful guide to the gas inflow rates and reservoir tube capacity when using the T piece

Age	Gas Inflow (litres/min)	Capacity of Reservoir Tube (ml)
0–3 months	3–4	6–12
3–6 months	4–5	12–18
6–12 months	5–6	18–24
1–2 years	6–7	24–42
2–4 years	7–8	42–60
4–8 years	8–9	60–72

Particular care must be taken when using the T piece in neuro surgery with the reservoir tube under the towels that it cannot become blocked It is a wise precaution to arrange a simple under water blow off on the inflow side of the circuit to give immediate warning of any obstruction This is a simple matter using a glass T piece a short length of rubber tubing and a wide bore glass connector under the water level in a standard transfusion bottle

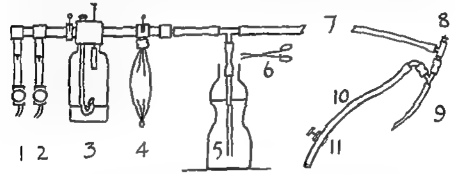


FIG 8

1 Oxygen flowmeter
2 Nitrous-oxide flowmeter
3 Vapourizing bottle
4 Reservoir bag with cut-off
5 Safety valve and monitor bottle
6 Clip
7 Inflow tube
8 Cobb s adaptor
9 Endotracheal tube
10 Expiratory tube
11 Clamp

Under water safety valve on the inflow side of T piece circuit The water level in the glass limb moves with respiration and will blow off if obstruction develops in the circuit A reservoir bag is included in the circuit together with clips for the safety valve and reservoir tubing so that the lungs can be inflated

This safety valve may also be used for observing respiratory move ments as the fluid level in the glass tube moves with respiration As it is occasionally necessary to provide artificial ventilation during neurosurgical operations in children we take the additional pre caution of having a reservoir bag available This is normally by passed but when required can be switched into the circuit At the same time the safety valve is clipped off and the clip on the reservoir tube partially closed so that the child s lungs may be inflated Finally it is an advantage to have the inflow and reservoir tube lying horizontally on the patient s chest as kinking is then

unlikely This is achieved by using two right angled connectors, one of these should have a cork so that suction is possible The whole circuit is shown in Fig 8 It is useful to have a stethoscope with a long lead applied to the precordium so that the breath sounds and the heart beats may be heard at a distance

McIntyre measured the distance from the upper incisor teeth to the vocal cords in 173 children and from these results recommends the following lengths of endotracheal tubes between the ages of 2 and 12 years

Age in years	2	3	4	5	6	7	8	9	10	11	12
Length in cm	13 25	13 25	13 75	14 25	14 25	14 5	15 25	15 5	15 75	16 25	16 5

Flexometallic tubes are used in children but sometimes when using sizes 0 to 2 Magill s armoured tubes may be preferred as the wall is thinner and the larger lumen available

Discussion

(a) Thiopentone

In the very young the aged and those in poor general condition a 2½% solution is substituted for the 5% and the minimum dose given In patients already unconscious intubation may be possible without anæsthesia, or with nitrous oxide oxygen and trichlor ethylene followed by suxamethonium In the case of head injuries the danger of aspiration of blood and C S F from the mouth and pharynx, or of regurgitated stomach contents must be remembered and the necessary precautions taken (See Chapter 9)

(b) Suxamethonium

The advantage of this short acting relaxant is that it provides ideal conditions for laryngoscopy spraying of the glottis and trachea, before intubation with large unbevelled tubes The dis advantages are—

(i) The short period of apnœa and possibly some accompanying rise in arterial and venous pressure

(ii) The possibility of prolonged apnœa

(iii) The muscle fasciculations and possible rise in intracranial pressure accompanying these as well as occasional post operative muscle pains [8, 9]

Clinically the short period of apnœa does not seem to affect seriously the intracranial pressure

If the dose of suxamethonium is kept below 50 mg then the likelihood of a very prolonged apnœa is reduced In most cases this will give adequate intubating conditions, however if the larynx is moving and the patient reacting a further dose is given If prolonged apnœa does follow suxamethonium then artificial respiration with positive or positive negative phase ventilation is continued until spontaneous breathing returns

The incidence of muscle pains in patients confined to bed is low [8] The administration of a small dose of gallamine triethiodide (Flaxedil) or *d* tubocurarine chloride prior to the induction of anæsthesia with thiopentone and suxamethonium has been advocated as a prophylactic measure to diminish the muscle fasciculation and post operative muscle pains [9] This has the added advantage that the rise in intracranial pressure that may accompany the twitching will not occur We prefer not to mix the types of relaxants given during induction

(*c*) Lignocaine hydrochloride

The use of 4% lignocaine to spray the trachea combined with lignocaine ointment on the endotracheal tube is most important as it helps to provide quiet operating conditions under light anæsthesia

In the occasional patient with a very brisk tracheal reflex the following procedure is helpful Thiopentone suxamethonium and lignocaine spraying are followed by the inhalation of nitrous oxide oxygen and trichlorethylene until the patient is settled and the local analgesic has had time to work Then a second dose of suxamethonium is given and the trachea intubated Bullough[10] has reported the occurrence of bradycardia and arrhythmia following second and third injections of suxamethonium We have confirmed this but have not observed any ill effects to result from it

(*d*) The airway

It is surprising to see the casual way in which endotracheal tubes are selected passed and fixed by some anæsthetists Those who give neurosurgical anæsthetics learn very quickly and painfully that the

utmost care and attention to the small details of intubation are essential for the safety of the patient and their own peace of mind The old adage that it is better to be safe than sorry, is nowhere more apt *The airway never gets better in the neurosurgical case* and must be perfect before operation begins

Endotracheal tubes and their connections may become obstructed in various ways [4]

Figure 9 shows how the rubber tubing of the catheter mounts can become kinked if it is too long This is easily avoided by shortening

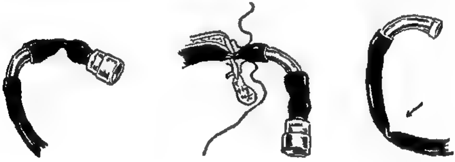


FIG 9 FIG 10 FIG 11

FIGS 9-11 Obstruction of endotracheal tubes

the catheter mount so that when attached, the metal of the endo tracheal connection and the mount are in contact No bending or twisting is then possible and the mechanical dead space is slightly reduced

Figure 10 If the metal endotracheal connector is not between the teeth or gums the patient may bite on the tube and obstruct it, particularly towards the end of an operation when anæsthesia is lighter and stimulation from scalp closure greater *This is prevented by inserting routinely a large airway in addition to the endotracheal tube*

Figure 11 A plain rubber oral endotracheal tube is shown kinking as it may with the patient's head flexed Once one of these tubes has been bent and kinked it will always kink subsequently at the same place These tubes are no longer used

Figure 12 Bourne's[11] metal flexible mouth tubes will reduce the likelihood of the above but with full head flexion this has still

occurred from sharp angulation of the rubber below the metal protector

Figure 13 Although the lumen of a portex tube is seldom com pletely occluded it may become narrowed particularly when softened by warmth These difficulties are overcome by using flexo metallic tubes[1] but two further precautions must be taken

Fig 12

Fig 13

Fig 14

Fig 15

Fig 16

Figs 12–16 Obstruction of endotracheal tubes

Figure 14 The unprotected soft rubber at the upper end of the flexometallic tube may become kinked This must be shortened so that the metal suction union can be pushed down as far as the spiral wire in the tube wall The suction unions are permanently attached to the tubes for their repeated insertion and removal can lead to the separation of the inner layer of latex and obstruction of the lumen

Figure 15 and Figure 16 The soft tip of the tube may become

bent or the bevel come to lie against the tracheal wall so that the airway is reduced This is particularly likely when the head is flexed and rotated To avoid this the bevel must be very short or preferably removed altogether (Fig 17)

In most adult male patients a size 11 tube is used and in female patients size 9 or 10 Talley s copper wire introducer (Fig 17)

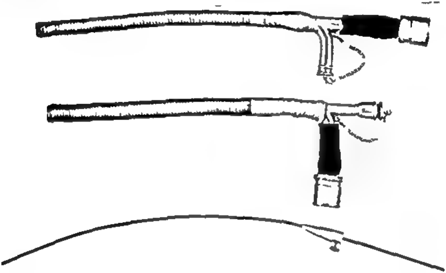


FIG 17 Flexometallic endotracheal tubes with bevels removed Short catheter mounts attached to different limbs of modified suction unions (Medical and Industrial Equipment Ltd) Talley copper wire introducer (Talley Anæsthetic Equipment Ltd)

suitably curved is inserted into the tube to facilitate intubation A small quantity of grease on the introducer makes withdrawal easy

Each size of tube is available in two or three lengths for it is vital that the tube is not so short that it will come out nor so long that it approaches the sensitive carina whatever the position of the head The tubes are sterilized by boiling for two minutes care being taken to pick them out of the sterilizer with forceps round the suction union Otherwise the metal rings will become flattened

The tubes are examined regularly for the small white areas that may give evidence of separation of the latex and the danger of

blister formation and obstruction of the lumen [13] In our experience this is very rare if the unions and tubes are never separated

A standard endotracheal suction union has been modified so that the catheter mount and cork will fit either limb (Fig 17) When the sitting position is to be used the catheter mount is attached to the vertical limb of the union normally used for suction so that with the head in full flexion the tubing lies conveniently on the chest and a double bend is avoided Rendell Baker[14] has described a straight endotracheal connector for use in cerebral angiography and posterior fossa operations

Waterproof strapping is also wrapped round the upper part of the tube to protect it from damage by the teeth

Occasionally while the upper respiratory tract airway is perfect with the flexometallic tube in position there may be obstruction in the lower tract from bronchospasm If this can be anticipated from pre operative examination then suitable preparation and premedication may avoid it Sometimes the bronchospasm may be a reflex response to a small amount of secretion and rapidly improves when this is removed If it persists then it may be overcome by intravenous pethidine in divided doses aminophylline 250–500 mg intravenously or more certainly by the inhalation of diethyl ether for 10 to 15 minutes in the anæsthetic room

If the patient reacts to the endotracheal tube by bucking and straining immediately the suxamethonium wears off then a further dose of 20–30 mg will stop this temporarily and when spontaneous respiration returns for the second time it will often be smooth and regular

If the bull necked plethoric type of patient does not settle well with trichlorethylene and tends to persist with a wheezing type of forced expiration a small dose of *d* tubocurarine chloride 8–12 mg intravenously will often improve this without reducing the tidal volume and in fact increase it

(*e*) **Pharyngeal packs**

There are some anæsthetists who recommend the use of packs routinely to prevent movement of the endotracheal tube during operation Pharyngeal packs must be used when there is a danger

of blood or C S F being aspirated in operations involving the air sinuses such as—

(i) Frontal craniotomy If the frontal sinuses are wide (Fig 18) and a large bone flap is to be elevated

FIG 18 X ray of skull showing frontal sinuses with large lateral extensions

(ii) Fractures involving nasal sinuses for which repair of anterior fossa dura is required

(iii) Pituitary tumours Large pituitary tumours may erode the hypophyseal fossa and possibly involve the sphenoidal sinuses (Fig 19) although more frequently the frontal sinus may be opened by a low frontal flap

(iv) Basal meningiomata · These tumours may open into the sinuses and require elevation of a low flap

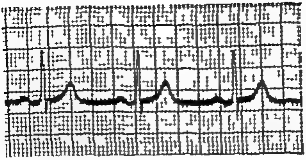
Cuffed endotracheal tubes and stomach tubes are used when there is the possibility of regurgitation of stomach contents as in head injuries and when patients are in the prone position A pack is unsatisfactory in these circumstances for while it will soak up blood and C S F coming from above it will not prevent stomach contents from entering the lower respiratory tract

FIG 19 X ray of skull showing erosion of hypophyseal fossa from a pituitary tumour

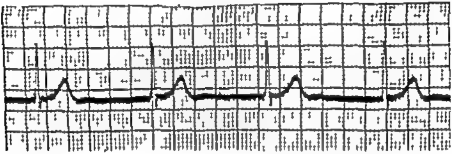
(*f*) Trichlorethylene

There are anæsthetists who will go to extraordinary lengths and develop complicated techniques to avoid using trichlorethylene Presumably they do this because they consider the drug to be dangerous particularly in relation to its cardiac effects It is well known that in common with other inhalation agents trichlorethylene may produce vagal hypertonia (Fig 20*a* *b* and *c*) and ventricular irritability[19] (Fig 21) but these have not been followed by more serious effects in our hands

Trichlorethylene has been used at St Bartholomew s Hospital since 1939 and in the neurosurgical unit since 1942 combined with



(a)



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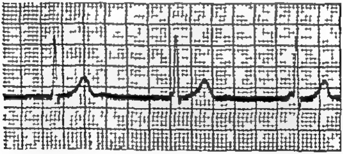


(c)

FIG 20*a* *b* and *c* E C G tracing showing development of nodal rhythm

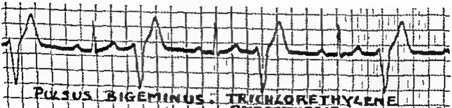


FIG 21 E C G tracing showing pulsus bigeminus during trichlorethylene anæsthesia

the infiltration of adrenaline in saline. No case of primary cardiac failure has occurred in this unit nor have there been any serious operative or post operative complications associated with its use. Our personal experience with it in other branches of anæsthesia over the past ten years has been similarly trouble free.

Occasionally if pulse irregularities persist the drug is discontinued. These irregularities rapidly disappear and may not return when trichlorethylene is reintroduced. If they do persist then other agents must be used, pethidine and thiopentone in small intermittent doses being alternatives.

The drug must only be used as an adjuvant to nitrous oxide and oxygen and not to induce anæsthesia alone or to attempt deeper levels. Once the patient has been induced with thiopentone and intubated after suxamethonium, trichlorethylene is used until an even pattern of respiration is established. There are some who doubt that the majority of patients can be settled in this way. It is our experience that with adequate topical analgesia and an unhurried induction a quiet transition is almost always the rule. After approximately 10 minutes the trichlorethylene concentration is reduced to the minimum that the individual machine will give, probably less *than 0.5%*.

For the past two years we have not used trichlorethylene on a major neurosurgical case without electrocardiographic monitoring. Langdon[18] working with us has analysed 90 consecutive cases with the following results—

E.C.G. Changes with Trichlorethylene

Total no. of cases	90
Total no. of E.C.G. changes	*30 (33%)*
	(15 (50%) of these changes developed within 30 minutes of the infiltration of adrenaline in normal saline.)
Ventricular ectopic beats	19
	(10 of these were within 30 minutes of the adrenaline saline infiltration.)
Nodal rhythm	8
T wave changes	1
Increased P.R. interval	1
Supraventricular ectopic beats	1

Barnes and Ives[17] say that on general medical grounds there is no reason to believe that vagal effects or simple premature contractions either auricular or ventricular are dangerous However in their series in which no thiopentone was given for induction multifocal tachycardia occurred in 10% We have not seen this change

In a recent survey of the literature of cardiac arrest during trichlorethylene anæsthesia and description of additional cases 15 incidents are described[18] In 11 of these no thiopentone had been given and trichlorethylene had been used either alone or with nitrous oxide and oxygen for induction In several trichlorethylene would seem to have been an unwise choice for the particular operation The committee investigating deaths associated with anæsthesia have also reported primary cardiac failure during trichlorethylene anæsthesia[19 20]

In spite of these reports from our own experience we are bound to agree with Ostlere[1] that while trichlorethylene can cause primary cardiac failure this is extremely rare provided the drug is used correctly

Trichlorethylene will result in tachypnœa if an overdose is given This may also arise even with low concentrations It is controlled by discontinuing the drug for short periods and giving 10 mg doses of pethidine

We believe that the blood pressure is unchanged by trichlorethylene Hunter[3] found that it raised the intracranial pressure and has also suggested that it was harmful in neurosurgery to patients with hypotension from hæmorrhage We have not observed these effects and in the case of hypotension find that anæsthesia can be maintained with nitrous oxide and oxygen alone

The great advantage of trichlorethylene is that it will provide hours of quiet light non explosive anæsthesia without respiratory depression and allows accurate assessment of the true condition of the patient It is cheap its post operative toxic effects are negligible and recovery is rapid provided that there is no over dosage

Apart from the cardiac irregularities and tachypnœa already mentioned its only disadvantages in neurosurgical practice are—

(i) It is sometimes too weak to settle the difficult fat plethoric type of patient

(ii) It is not ideal in children as tachypnœa is common and difficult to control

(*g*) Halothane (Fluothane)

2 bromo 2 chloro 1 1 1 trifluoroethane or halothane (Fluothane) was studied pharmacologically by Raventos[3] and has been used clinically since 1956 [4 6 27 28 9 30 31] Its use in neurosurgical anæsthesia has been described [3 33 34] We have been using halothane during the past year and comparing it with trichlorethylene during neurosurgery

Halothane has been used with the Fluotec (Cyprane) Vaporizer and a semi closed circuit with a total flow rate of 10 litres per minute and high percentage of oxygen This is an extravagant but safe method The cost of halothane using this method in a neuro *surgical case is approximately 12s 4d per hour while the cost of* trichlorethylene used as we have already described is 2d per hour It is equally safe but less expensive to use the Fluotec with a total flow rate of 4 litres per minute with either a circle or to and fro absorber in the semi closed circuit The semi closed circuit is better for neurosurgical practice as it is simpler and we believe offers less resistance to respiration

Langdon[16] has found electrocardiographic changes in our cases as follows—

E C G Changes with Halothane

Total no of cases	82
Total no of E C G changes	18 (22%)
	(14 (77%) of these changes developed within 30 minutes of the infiltration of adrenaline in normal saline)
Ventricular ectopic beats	7
	(6 of these were within 30 minutes of the adrenaline saline infiltration)
Nodal rhythm	7
T wave change	1
P wave change	1
Supraventricular ectopic beats	2

Atropine was not used in all these patients although adrenaline in saline was injected in the usual way before the skin incision

Atropine should be given before halothane for it has been pointed out that in conventional dosage hyoscine has little blocking action on the cardiac vagus and is not a suitable alternative[2] Elsewhere electrocardiographic evidence has been presented to show the potential hazards of combining halothane with subcutaneously injected adrenaline[3]

There is no doubt that halothane provides an excellent alternative to trichlorethylene in neurosurgery

It has some advantages—

(i) It is more powerful and therefore may be more effective in the difficult patient

(ii) It is better in children as much quieter anæsthesia with lower respiratory and pulse rates are combined with a rapid recovery

(iii) Its hypotensive action if carefully controlled is of particular value in most neurosurgical cases

It potentiates the action of the ganglion blocking agents reducing the number of patients resistant to the hypotensive agents and lessening the quantity of these drugs used

(iv) Recovery of full consciousness is more rapid

In other ways it is less satisfactory than trichlorethylene—

(i) It reduces the tidal volume of most patients even in concentrations of 0 5% by volume Severe reduction may occur while the patient is still too lightly anæsthetized for surgery

(ii) Cardiovascular complications are more common particularly when high concentrations are needed These may occur suddenly and unexpectedly even with low concentrations Figure 22 illustrates the care with which the blood pressure level and pulse rate must be watched at all times even in routine operations on fit patients

(iii) Severe hypotension may occur if it is used in cases in the sitting and prone positions

(iv) It is many times more expensive when given by the semi closed method

Induction and intubation are carried out in the usual way and halothane turned to 0 5% when spontaneous respiration returns It may have to be increased to 1% or 1 5% until the patient is settled and the operation begun Occasionally a patient appears to be adequately anæsthetized and yet reacts to the positioning of the

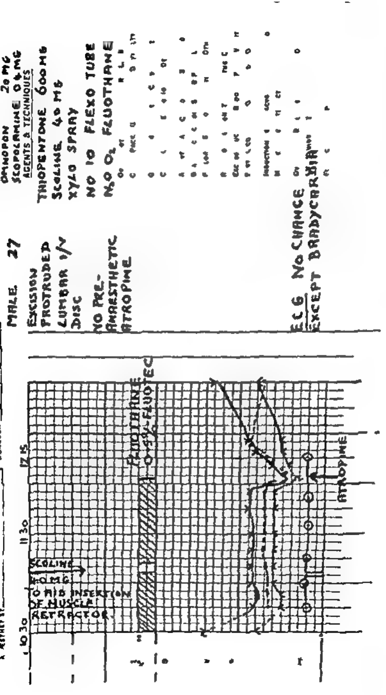


FIG 22 Fit male of 27 years undergoing excision protruded intervertebral disc Anæsthetic chart showing sudden bradycardia and additional fall in blood pressure during nitrous oxide oxygen and 0 5 / halothane anæsthesia The effect of atropine gr 1/200 (0 3 mg) intravenously is shown

head or skin incision Usually 0 5% is sufficient for maintenance and the halothane may be turned off altogether from time to time but the rapidity with which reflexes return must be remembered

Some fall in blood pressure is the rule but with concentrations of halothane between 0 5% and 1% the systolic level seldom falls below 80 mm Hg (Fig 23) Tachypnœa may develop soon after induction It is controlled with pethidine and seldom persists Recovery is rapid and post operatively there has been no trouble from excessive vomiting renal or liver damage

In children nitrous oxide oxygen and halothane may be used for induction and relaxation of the masseters with good intubating conditions follow quite quickly Halothane is then continued for the maintenance of anæsthesia with semi-closed circuit or Ayre s T piece depending on the size of the child Alternatively induction and intubation are with ethyl chloride and open ether or nitrous oxide oxygen and ether In older children halothane may be used as in adults following intubation with thiopentone and suxa methonium Halothane was used with the modified Ayre s T piece circuit described for prolonged anæsthesia during the separation of craniopagus Siamese twins Anæsthesia was smooth throughout and the condition of the children surprisingly good at the end of the operation The anæsthetic charts are shown in Fig 24 as they may be of interest

It is too early yet to predict the place that halothane will occupy in neurosurgical anæsthesia There are some who consider a serious disadvantage derives from its hypotensive action which may appear before an adequate level of anæsthesia has been attained [3] We feel its greatest disadvantage is its depressant effect on respiration particularly when this occurs in patients with raised intracranial pressure

At this early stage it would seem that this powerful drug so closely resembling chloroform is potentially more dangerous than our experience has shown trichlorethylene to be However it has certain advantages of particular value in neurosurgery

As the clinical trials of halothane in neurosurgery extend it would seem advisable to—

(i) Use atropine in the premedication

4

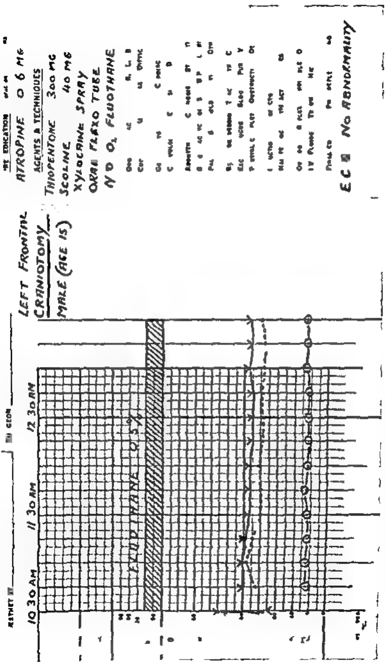


FIG 23 Frontal craniotomy for removal of orbital tumour in a boy of 15 Typical anæsthetic chart and good operating conditions with nitrous oxide oxygen and halothane

(ii) Use a semi closed circuit with a controlled percentage vapourizer

(iii) Avoid concentrations above 2% by volume at any time and expect to maintain anæsthesia with 0 5 to 1%

(iv) Maintain spontaneous respiration

(v) Take particular care if using it in combination with the sitting prone or steeply reversed Trendelenburg positions

(vi) Record the blood pressure and pulse rate in every case at frequent intervals

(*h*) **Pethidine**

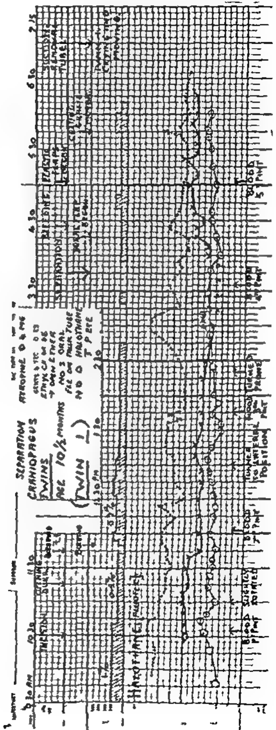
In 1952 Kepes[35] reported that though morphine and pethidine given intravenously almost invariably elevated C S F pressure, in the case of pethidine the degree of rise depended on the dose Nisentil hydrochloride and many other drugs have been shown to be associated with a rise in C S F pressure[36]

In practice we have found the use of small doses of pethidine given intravenously in a dilute solution containing 10 mg per ml, to be invaluable in controlling the tachypnœa of trichlorethylene and halothane as well as providing additional analgesia. Two or three injections of 10 mg early in the anæsthetic are usually sufficient The respiratory rate is used as a guide to dosage and pethidine is not given if this is below 24 per minute If the respiration is shallow or irregular from raised intracranial pressure effects then neither pethidine nor any other respiratory depressant should be given Later in anæsthesia for craniotomy when the bone flap has been raised and trichlorethylene or halothane turned off from time to time tachypnœa is not usually troublesome

(*i*) **Anæsthetic circuits**

We have tried various forms of adult T piece to and fro and circle absorbers but believe that a semi closed circuit with Magill re breathing attachment and valve is the simplest and most efficient practically in adult patients and the Ayre s T piece in children modified as we have described

For the average adult patient with normal metabolic rate and corresponding ventilation a flow of fresh gas of 7 litres per minute


SEPARATION
CRANIOPAGUS
TWINS
AGE 10½ MONTHS
(TWIN 1)
HALOTHANE

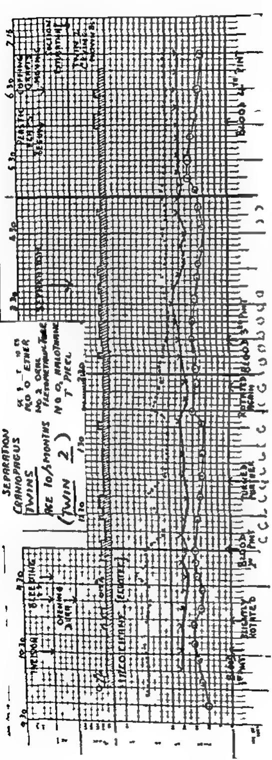


FIG 24 Anæsthetic charts of operation for separation of conjoined craniopagus twins Note the relatively low pulse rates in spite of the severity of the operation In both the blood pressure remained steady except for a period of 1 hour when it could not be recorded in twin 1 Note the very large amount of fresh blood required to replace blood loss

into a Magill s attachment has been shown to limit the percentage of carbon dioxide re breathed to a satisfactory level [3] Resistance to breathing is less in the T piece circuit[38] and provided the inflow of fresh gas is twice the minute volume and the cubic capacity of the reservoir tube is equivalent to one third of the patient s tidal volume, there should be no dilution of anæsthetic or undue accumulation of carbon dioxide [6 39]

The increased resistance to respiration that we believe occurs if carbon dioxide absorbers are included in the circuit has discouraged us from continuing their use in neurosurgery

(j) **Alternative methods**

Almost any combination of local and general anæsthetic drugs can be used Alternative methods that allow spontaneous respiration must necessarily differ from the technique described either in the substitution of trichlorethylene or halothane by intravenous anal gesics heavier premedication local analgesia other inhalation agents (chloroform being the only other non explosive drug) or in the use of a different circuit

Recently the use of controlled respiration with positive negative ventilation has been described[40 41 4] and offers a further alternative

Controlled respiration The use of controlled respiration with light anæsthesia and muscle relaxants in chest and abdominal surgery is now well established and in the hands of the well trained anæsthetist is safe and efficient and associated with very little operative or post operative trouble The use of controlled respiration with *positive* pressure ventilation alone in neurosurgery is advocated by some[4] who consider that it improves operating conditions Others believe that as the normal negative inspiratory phase of the thoracic pump is abolished venous return is held up and venous pressure in the head raised Positive atmospheric pressure inflation has been shown to produce a rise in pressure in the fourth ventricle [43] The mean œsophageal pressure in paralysed patients receiving intermittent positive pressure respiration from a Radcliffe respiration pump has been shown to be raised [44] Venous return to the heart is impeded by an amount equal to this rise During spontaneous inspiration the œsophageal pressure was shown to fall

If a *negative* phase is added and the normal thoracic pump action imitated, then it is claimed that[39 40 41 4] —

(i) Intracranial tension is low

(ii) Recovery from anæsthesia is immediate

(iii) Post operative brain swelling is reduced

(iv) Volatile anæsthetic agents are avoided

(v) Blood loss is reduced

(vi) Adequate oxygenation and carbon dioxide elimination are maintained even in the presence of central respiratory depression

(vii) The effects of the face down position are minimized

(viii) Post operative vomiting is reduced

(ix) The possibility of straining during anæsthesia is reduced

The principal disadvantage which is admitted by some protagonists of the method is that it will not be acceptable to a unit that depends on respiratory changes to give information about intracranial pressure and damage to medulla and other intracranial structures

Other possible disadvantages are—

(i) Air embolism

(ii) Sub dural hæmatoma arising from the tearing of anastomotic veins when the intracranial pressure is very low

(iii) The complications dependent on the use of prolonged artificial ventilation the muscle relaxants and their antagonists

(iv) The necessity for and dependence upon a mechanical respirator

Mortimer[45] believes that the risk of air embolus is less under controlled respiratory conditions as deep inspiratory gasps and sudden diminution in intrathoracic tension are not possible where respiration is completely controlled He does believe that the masking of disordered respiration is a valid objection when operation near the medullar vermis or floor of the fourth ventricle is being undertaken In these circumstances he restores natural respiration

We will not describe the techniques recommended as we do not use them in neurosurgery but they depend on full curarization with controlled positive negative ventilation using endotracheal nitrous oxide and oxygen

While this remains a controversial subject in neurosurgical anæsthesia it is our view that it is safer to use the physiological negative inspiratory pressure of spontaneous breathing and not to interfere with natural respiration unless it is inadequate.

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Chapter 4

METHODS OF LOWERING INTRACRANIAL PRESSURE

THE effects of a raised intracranial pressure and the mechanism of medullary failure have been discussed

It will be realized that while every attempt is made to prevent the pressure from rising it must be lowered rapidly if there is interference with medullary function Much of the responsibility for this lies *with the anæsthetist not only in recognizing the signs of impending medullary failure* but in carrying out various procedures to avoid this

1 Ventricular tap

This is performed by the surgeon and consists of passing a needle into the lateral ventricle and allowing the C S F to run out gradually until the pressure falls It is the most direct and effective method but can only be done rapidly if burr holes are present or a bone flap raised Fortunately ventriculography frequently precedes craniotomy so that in many cases requiring anæsthesia there are burr holes already present

The ventricles can be tapped rapidly if for example a rising pulse rate or respiratory failure should follow induction of anæsthesia (Fig 25) If the brain is tense when the dura is exposed the surgeon will often lower the pressure by tapping the ventricles before elevating the dura In this way herniation and damage to brain tissue is avoided and subsequent surgery facilitated

In cases of hydrocephalus with large ventricles and a very high pressure ventricular drainage may be used to prepare patients for operation A ventricular drainage tube is left *in situ* and C S F allowed to escape slowly Sometimes ventriculography precipitates a rise in intracranial pressure and the patient s condition deteriorates before anæsthesia is induced There would seem to be a possible indication for ventricular drainage in these circumstances

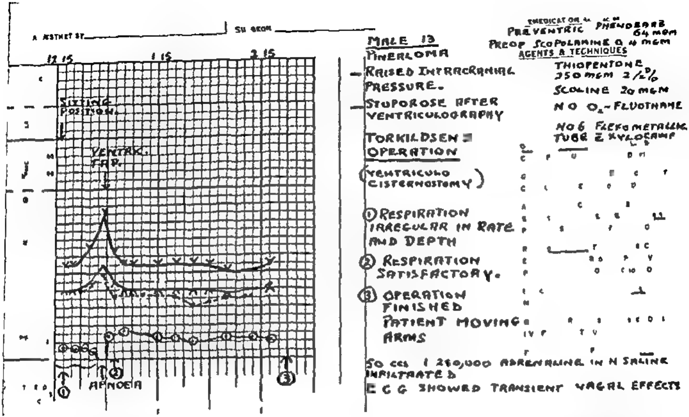

FIG 25 Thirteen year old boy with a pinealoma and raised intracranial pressure undergoing ventriculo cisternostomy Anæsthetic chart showing the respiratory and cardiovascular effects of a rising intracranial pressure and the immediate value of ventricular tap

2 Spinal drainage

This may be used as an adjunct to intracranial operations It consists of the controlled withdrawal of C S F from the lumbar subarachnoid space during surgery, and occasionally in the wards During the operation of hypophysectomy, for example, C S F wells up into the basal cisterns and hinders the surgeon, spinal drainage will reduce this

Ray[1] relies on the use of a No 17 spinal needle with a small eye in the side to provide thorough drainage This is connected to a tube and 50 ml collecting syringe Ray has used the method on 350 hypophysectomies He also uses spinal drainage in other types of intracranial surgery when it seems appropriate but in the presence of a raised intracranial pressure is particularly careful not to allow loss of spinal fluid until the dura is open The principal reason is that coning may be precipitated and if veins are torn in the process of elevating the bone flap blood may fill the sub dural space and be difficult to remove Ray considers that there is no particular merit in replacing the fluid and of course stresses that if there is any question of contamination it should never be reinjected

In the wards spinal drainage is occasionally advantageous and vinyl plastic tubing may be passed through a Tuohy needle with curved directional Huber point - or wide bore spinal puncture needle and left *in situ* It may then be connected by a Southey s tube to a drainage flask clamped to a vertical bar at the head of the bed and the height varied to regulate drainage[3] Polythene tubes are not very satisfactory for use in the theatre as fluid cannot be rapidly removed through them

3 Dehydration therapy

The C S F pressure falls profoundly for a period of 2 to 4 hours if hypertonic saline is injected intravenously This acts by raising the crystalloid osmotic pressure of the plasma Water consequently flows from the interstitial fluid into the plasma and secondarily from the cells into the interstitial fluid The brain therefore shrinks In addition the rate of absorption of C S F is increased and there may also be a reversal of cerebro spinal fluid flow[4]

Sucrose In neurological practice 100 ml of 50% sucrose injected

intravenously is the solution of choice. Sucrose is preferred for the following reasons[5]—

(*a*) It does not pass into the C S F and produce the secondary rise in pressure as does glucose [6, 7]

(*b*) It is not stored in the tissues like sodium chloride or gradually metabolized like glucose

(*c*) It is almost completely excreted by the kidneys producing a diuresis and is not followed by rebound œdema

Sucrose is used in the ward up to four hourly and may be required to reduce brain tension during operation. As already mentioned it is an advantage to have a Mitchell needle[8] in the foot during craniotomy which may be used for the rapid injection of sucrose. The solution will damage the tissues if injected extravenously so that it is important to ensure that it goes into the vein, and also to follow it with 50 ml of normal saline in an effort to avoid permanent damage to the vein. Sucrose may also cause local tissue damage if it is injected into a peripheral vein in the presence of peripheral circulatory failure

Some surgeons dislike the use of sucrose and there is evidence to suggest that it should not be used in renal and cardiac cases [9]

Plasma To produce a more sustained fall of intracranial pressure hypertonic plasma was introduced in 1938 [10] More recently triple plasma has been recommended[11] in severe head injuries (see Chapter 9)—

(*a*) To prevent cerebral œdema

(*b*) To treat surgical shock

(*c*) To reverse coning

The solution is made up by mixing the dried plasma of 3 pints of blood with 400 ml of sterile water

The use of vigorous dehydration therapy to combat the cerebral œdema that follows acute hypoxia has also been described [12]

Magnesium sulphate More gradual and prolonged decompression is obtained by the rectal administration of magnesium sulphate. Three ounces of magnesium sulphate are made up in 6 oz water and this 50% solution is run into the rectum at body temperature in 15 to 20 minutes. The procedure may be repeated twice daily and the maximum effect is evident after three or four days [13] In some

units magnesium sulphate is used fairly routinely following craniotomies and is preferred to sucrose mainly on the grounds of greater simplicity [14]

Urea The use of a 30% solution of urea in invert sugar in water is undergoing clinical trial in the U S A and simultaneously in this country The solution is administered intravenously over a period of 1 to 2 hours to lower the intracranial pressure The recommended dose is between 1 g and 1 5g per kilo of body weight and the maximum dose should not exceed 1 5 g per kilo The maximum effect is said to occur within 1 to 2 hours and to persist for periods of from 3 to 10 hours

Urea causes a marked diuresis and it is recommended that an indwelling catheter should be inserted before administration of the solution and the urinary output measured Poor renal function should be considered a contra indication

Fluid intake The fluid intake is restricted in cases of raised intracranial pressure (See Chapter 11)

4 Posture

The fluid in the subarachnoid space of the brain and spinal cord may be regarded as a single column The change in pressure produced by a change of position can largely be predicted by hydrostatic considerations The pressure in the lumbar and occipital regions is identical when the subject is horizontal In the cisterna magna in the erect posture the pressure is probably below atmospheric For this reason the head end of the operating table is raised in all intracranial and spinal operations and this tilt will be increased when the brain is tense It is useful to have a raised platform from which the surgeon can gain surgical access even with a steep tilt

The blood pressure and particularly venous pressure will also tend to fall in the head raised position and the patient s posture on the table must be so arranged that there is no obstruction to venous drainage away from the operation site

5 Hypotensive techniques

(*a*) **Ganglion blockade** The extension of posture and its combination with ganglion blocking agents was described by Enderby[15] in

in 1950, as a means of reducing operative bleeding The low blood pressure obtained helps to keep the intracranial tension low and facilitates neurosurgical procedures[17] Originally controlled hypo tension in neurosurgery was confined to operations for aneurysms and vascular tumours[18] With the introduction of new drugs and the increased safety that has accompanied increased experience, the scope of the technique has been widened Today it is sometimes used to lower intracranial tension at operation irrespective of the amount of bleeding anticipated (See Chapter 5)

A technique combining the use of ganglion blocking agents and a negative pressure to the legs has been described[19] The advantages claimed are that it should be possible to obtain a bloodless operating field in a larger proportion of patients using smaller doses of hypotensive drugs Also that when leg suction is used the blood pressure may be raised or lowered in a few seconds by regulating the negative pressure and thus the postural effect

(*b*) Arteriotomy This method was introduced in 1946 to lessen hæmorrhage in neurosurgery[20] and its use extended in subsequent years[1, 22–23, 1–5] There is no doubt that this was a most effective method of reducing bleeding and brain tension However the danger of tissue damage from the combination of arteriolar con striction and hypotension plus the use of complicated apparatus has reduced the popularity of the method in favour of the hypo tensive drugs

6 Hypothermia

Rosomoff and Gilbert[26] recommended the use of hypothermia in neurosurgery after observing a reduced brain volume when experi menting with dogs Reporting this at the Royal Society of Medicine Rosomoff gave the following figures—

(*a*) Cerebral blood flow decreased at a rate of 6 7% per degree centigrade

(*b*) At 25°C metabolism and blood flow were one third of the pre cooling level

(*c*) Reduction in the brain volume of 4 1% at 25°C which in man would amount to a change of 55 ml

(*d*) The C S F pressure also decreased at a rate of 5 5% per degree centigrade

Some clinical workers have found that the brain is contracted intraventricular pressure is often atmospheric or sub atmospheric and bleeding not troublesome even when the blood pressure is not low [8]

In our own experience while we have always had good operating conditions with hypothermia we do not think that these have been sufficiently improved to warrant the use of the method for this purpose alone We consider that it should only be used when it is required to protect the brain from the effects of ischæmia (See Chapter 6)

The use of hypothermia and autonomic blockade are often combined [28 29 30] Gray[31] has suggested that surface cooling down to 30°C should be regarded as an adjuvant to hypotension in most if not all cases

The application of hypothermia in acute head injuries was reported in 1954[32] and its subsequent use as a therapeutic measure in reducing cerebral metabolism and brain volume over prolonged periods confirmed [33 34 35 11] We have personal experience of hypo thermia used in similar circumstances

In the experience of others hypothermia does not further reduce the morbidity or mortality rate nor does it improve operating conditions sufficiently to be worthy of comment [36]

7 Intermittent positive-negative pressure respiration

This has been mentioned in Chapter 3 [3 38 39] It is included here as the principal advantage claimed is the low intracranial tension achieved with normal arteriolar vascularity and blood pressure [38]

Measurement of pressures in the 4th ventricle has shown that the pressure is lower during positive negative inflation than during spontaneous respiration [39] In some centres where spinal drainage was practised during hypophysectomy the method has been replaced by positive negative ventilation as this is considered more uniformly helpful [3 38]

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Chapter 5

CONTROLLED HYPOTENSION

THE use of ganglion blocking agents to induce controlled hypo tension in neurosurgery has increased the scope and safety of certain operations While the method must never be used for the con venience of the surgeon if it facilitates his work to such an extent that it affects the success of the operation and increases the patient s chance of survival then it is justifiable

In neurological surgery highly vascular tumours and aneurysms are often deeply placed They have to be approached by narrow pathways and uncontrollable arterial bleeding or continuous oozing at any stage will completely obscure the operative field and imperil the patient The use of controlled hypotension combined sometimes with hypothermia allows these operations to be performed with greater confidence operating time is reduced trauma and blood loss are less and post operative recovery is quicker In fact, it may make possible operations that were previously impossible

Uncontrolled hypotension is undoubtedly extremely dangerous [1] and its use with uncontrolled anæsthesia is more so Provided however that the method is used by careful experienced anæsthetists who are aware of its hazards and have weighed up the indications and contra indications with the patient s welfare in mind it is of great value in neurosurgery The disadvantages and dangers have been presented by Little and others [3]

Originally arteriotomy was used in these cases but since then various techniques using the ganglion blocking agents have been described [4 5 6 7 8 9 10 11] Some anæsthetists[1 13] have found that with the use of controlled positive negative phase respiration in neuro surgery induced arterial hypotension by arteriotomy or ganglion blockade is very rarely if ever needed

Indications

Hypotensive anæsthesia is indicated primarily when the possibility of severe hæmorrhage exists We and others [5 6] believe that the

fall in intracranial pressure that accompanies the lowering of arterial pressure is also an advantage in neurosurgery and therefore regard the following as indications—

1 Vascular abnormalities
   (*a*) Aneurysms
   (*b*) Angiomata
2 Meningiomata
3 Very high intracranial pressure

Brown[14] considers the use of induced hypotension to be unsafe in patients with a severe increase in supratentorial pressure and trans tentorial displacement He believes that as the mid brain arteries are already stretched and partially occluded fatal ischæmic brain stem damage may be precipitated by the fall in blood pressure We have not experienced this In these cases the blood pressure is not lowered until the bone flap has been raised and the tension of the dura and underlying brain confirmed The arterial pressure is lowered before the dura is opened to minimize the possibility of injury due to herniation of brain tissue as the dural flap is elevated

Contra indications

It is difficult to be dogmatic about these in neurosurgical practice as hypotension is never considered unless it is thought likely to benefit a patient who is already seriously ill If there is definite evidence of renal hepatic or cardiac disease these will usually have to be considered absolute contra indications However as Davison[9] has pointed out it is only with difficulty that the existence of some of these diseases can be excluded pre operatively Blood urea estimations and electrocardiography are carried out routinely before operation

We agree with Aserman[6] that it is foolhardy to use the method for operations in the sitting or very steeply reversed Trendelenburg position such as posterior fossa explorations or craniectomies for division of the Vth sensory nerve root Moreover it is quite un necessary as in this position bleeding is minimal anyway It is similarly dangerous in the prone position with a foot down tilt as the blood pressure is almost always low without the addition of ganglion blocking agents

Retractor anæmia [6] is not regarded as a danger by O Connell [15] provided that gentle unhurried surgery is the rule In fact, if brain tension has been lowered by hypotension then less vigorous retraction is required

Controlled hypotension is not needed and would be dangerous in patients for hypophysectomy who have already had bilateral adrenalectomy

Finally it must be stressed that the induction of hypotension is absolutely contra indicated if the general anæsthetic being given is in any way unsatisfactory The airway and oxygenation must be perfect with a warm pink dry skin, and spontaneous respiration regular with a good tidal exchange Obviously efficient blood pressure recording apparatus must be available and not least the technique should never be used by untrained personnel

Whereas the indications are relatively few the absolute contra-indications are—

1 Renal disease
2 Hepatic disease
3 Cardiac disease
4 The sitting prone and steep reverse Trendelenburg positions
5 Previous bilateral adrenalectomy
6 Unsatisfactory anæsthesia
7 Absence of trained personnel

Technique

Anæsthesia is induced in the way described using nitrous oxide oxygen and trichlorethylene or halothane for maintenance The head end of the table is raised 5–10° the usual solution of adrenaline in normal saline 1/500 000 infiltrated and the operation begun

The blood pressure pulse and respiration rate are recorded and E C G tracings obtained The hypotensive agent is not used during this preliminary stage of the operation but is reserved for the period when it will be of greatest value In this way the dosage is kept low and it has been found just as satisfactory to induce hypotension at this later stage in the operation

The drug of choice is the thiophanium derivative trimetaphan camphorsulphonate (Arfonad) With this short acting drug used

in dilute solution delicate control is possible The longer acting methonium drugs and pendiomide are more difficult to control as with them an all or none' type of induction is difficult to avoid After the initial dose the blood pressure may be too low or practically unaffected depending on the reaction of the individual It may then be difficult to establish equilibrium We have not found the homatropinium derivative trophenium[16] to have any advantage over trimetaphan although it is used in the same way, and we have been alarmed by some very high pulse rates during its use

Trimetaphan was first used in this country in 1953[17] When used with trichlorethylene it is either given as a drip using a 0 2% solution in normal saline (1 g in 500 ml) or by electrically driven syringe[18] with a 1 25% solution (250 mg in 20 ml)

Rate of dosage

1 With trichlorethylene The initial rate of administration depends on the age general condition and blood pressure of the individual patient Generally it is rapid but in the aged ill and those who already have a low blood pressure the induction of further hypotension must be cautious In hypertensive patients too it is often found that the initial fall of blood pressure is precipitous even with small doses (Fig 26) and in these cases the pressure should be maintained above 70 mm of mercury

In the average patient trimetaphan is started at a rate of up to 8 mg per minute or a drip rate of 70 drops per minute Continuous blood pressure readings must be taken while this high dosage is being given and when the systolic pressure begins to fall the drip or syringe rate must be reduced at once or stopped altogether The fall in blood pressure is almost always preceded by some rise in pulse rate Generally an attempt is made to maintain a systolic pressure of 70 mm of mercury recorded by auscultation Some anæsthetists[19] have found that it is not necessary to lower the pressure below 90 mm of mercury and others[20] suggest that it should not fall below 80–85 mm of mercury in normotensive patients We believe that the pressure should never fall below 60 mm of mercury unless the patient has been rendered hypothermic and then only for short periods during vital steps in the surgery of

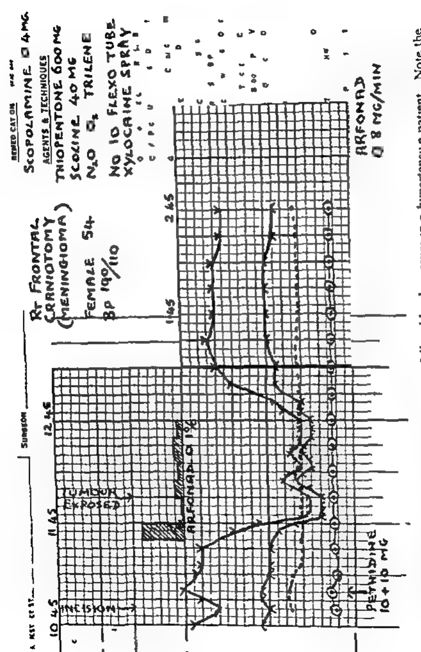

FIG 26 Anæsthetic chart showing precipitous fall in blood pressure in a hypertensive patient Note the small quantity of trimetaphan required and the immediate rise in blood pressure when its administration was stopped

aneurysms Often operating conditions are satisfactory at a higher systolic pressure and this is to be desired The lowest rate of dosage is found that will maintain the blood pressure at the highest level compatible with a fairly dry operative field and lax brain This is not always easy for in some patients the blood pressure will not fall below a certain level in spite of large doses This diminishing response of the blood pressure to ganglion blocking agents has been shown to be due to an increased sensitivity of the effector cells to adrenaline and noradrenaline [21]

The dosage rate in our patients falls into three groups and shows the wide variety of response The series of 139 cases using trimetaphan with nitrous oxide oxygen and trichlorethylene anæsthesia by the method described is small but this is to be expected if it is used with discrimination

Trimetaphan with trichlorethylene anæsthesia

	Dosage (mg /min)	No of Cases	Per cent
Group I	0-3 9	72	51 8
Group II	4-7 9	43	30 9
Group III	8 +	24	17 3
		139	100 0

We have not found a definite relationship between the dosage and the age or weight of the patients although the older patients tend to be in Group I

It may become necessary to increase the rate of dosage to maintain the desired systolic pressure as time passes (Fig 27) Whenever possible the rate is reduced as the operation proceeds (Fig 28)

The pulse rate usually rises (Figs *29a* and *b* 30 and 31) and sometimes remains high throughout the administration (Fig 32) More often it gradually slows (Fig 33) while occasionally the pulse rate is almost unaffected (Fig 34) We have found that a raised pulse rate may persist even when there is no significant reduction in

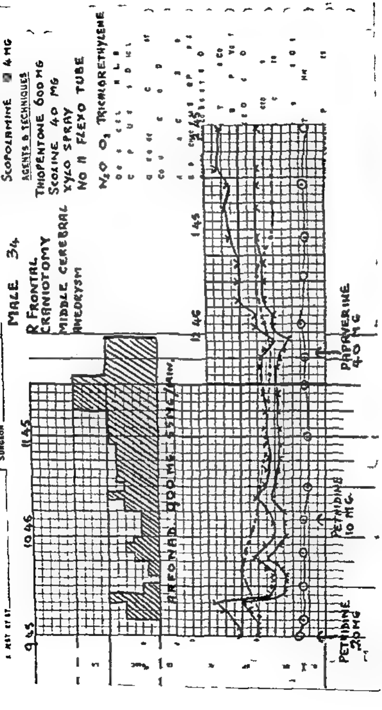

Fig 27 Anæsthetic chart showing the increasing dosage rate of trimetaphan required to maintain hypotension Note the absence of tachycardia in spite of this

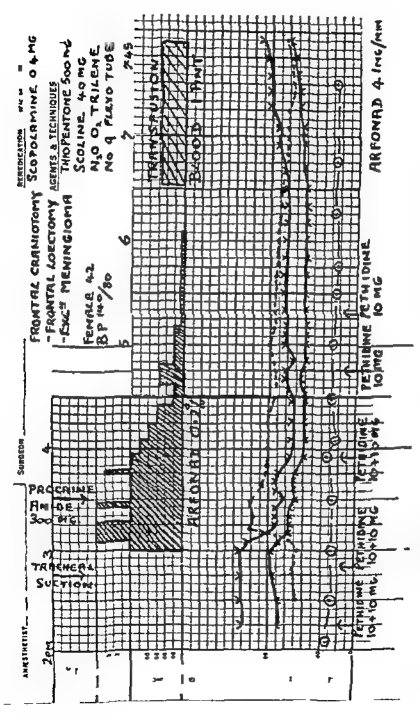

FIG 28 This anesthetic chart shows the gradual reduction in trimetaphan dosage that was possible It also shows the slow *recovery of blood pressure* the use of blood transfusion and the unusually high dosage of pethidine required in an attempt to combat tachypnœa

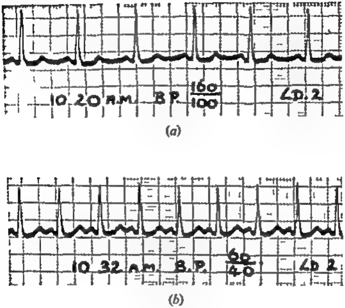

FIG 29a and b E C G tracings showing a rapid rise in pulse rate accompanying the fall in blood pressure from trimetaphan

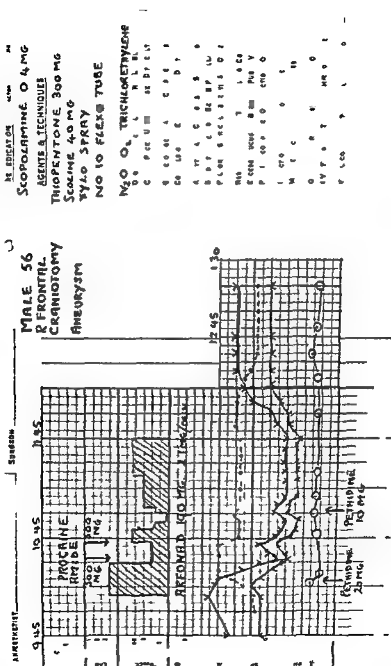

FIG 30 The pulse rate rapidly rose to 140 in this chart and then fell slightly possibly due to the use of procaine amide

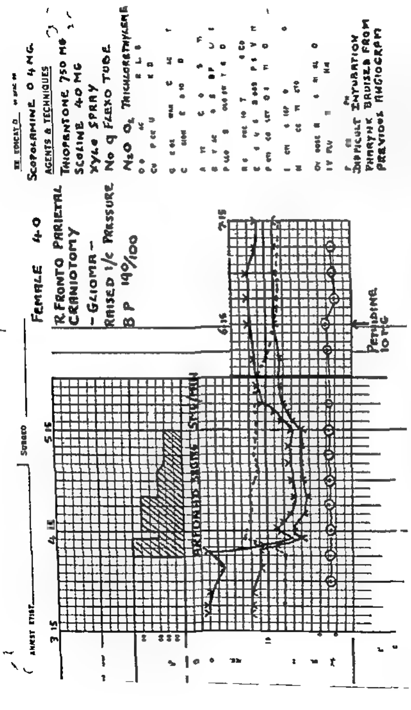

FIG 31 This anaesthetic chart again shows a precipitous fall in blood pressure in hypertensive patient with raised intracranial pressure The pulse rate rose rapidly following induction of hypotension

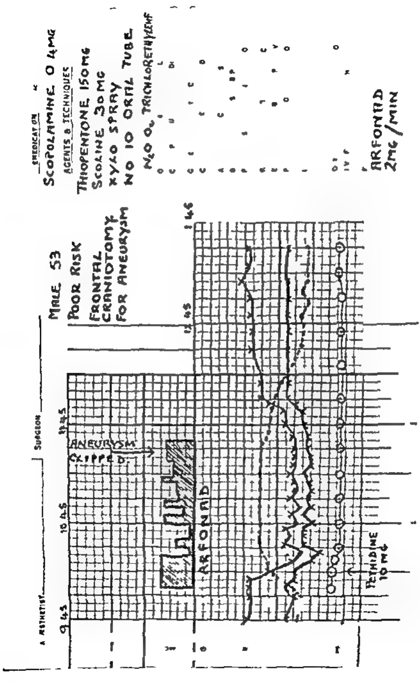

FIG 32 This chart shows persistent tachycardia throughout the administration of trimetaphan

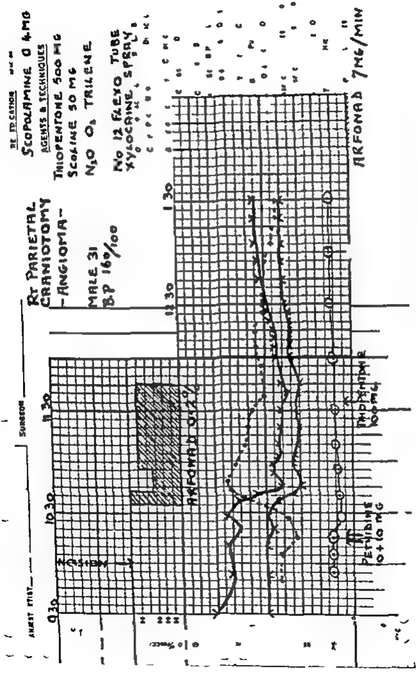

FIG 33 The pulse rate in this case shows a rapid rise and the more usual gradual fall during the hypotensive phase

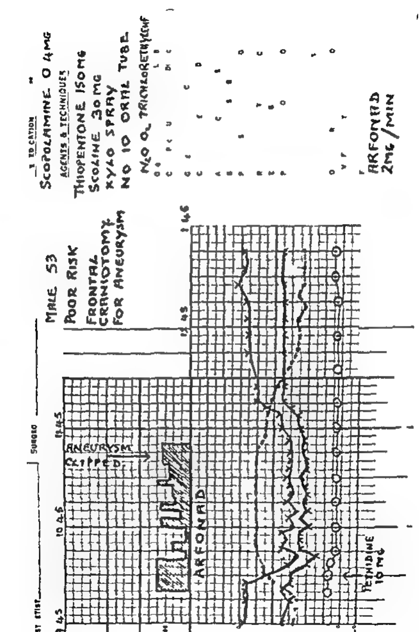

FIG 32 This chart shows persistent tachycardia throughout the administration of trimetaphan

blood volume We would expect the rate to remain high in the presence of blood loss [11]

It is important to remember that in the occasional neurosurgical case quite severe bleeding may still occur even when the blood pressure has been reduced with a hypotensive drug This is a dangerous state of affairs as the blood volume will fall and must be restored rapidly with transfused blood (Fig 35)

2 **With trichlorethylene and hypothermia** In the few cases in which trimetaphan has been used during hypothermia the dosage rate required has been unexpectedly high

Trimetaphan with trichlorethylene anæsthesia and hypothermia

	Dosage (mg /min)	No of Cases	Per cent
Group I	0–3 9	4	25
Group II	4–7 9	4	25
Group III	8 +	8	50
		16	100 0

3 **With halothane** Since we have been comparing halothane with trichlorethylene in neurosurgical cases it has become obvious that with the former much less trimetaphan is required This is to be expected as peripheral vasodilatation and hypotension occur with halothane alone It means that great caution must be used when inducing further hypotension with trimetaphan or any other ganglion blocking agent and an initial rate of 1 mg per minute is not exceeded and the strength of the solution used is diluted

Resistance and maximum dosage

When we first started using trimetaphan it was our practice in patients who showed resistance to the drug to keep increasing the rate of dosage One such patient developed anuria post operatively and died on the eighth day In this case of cerebral aneurysm although

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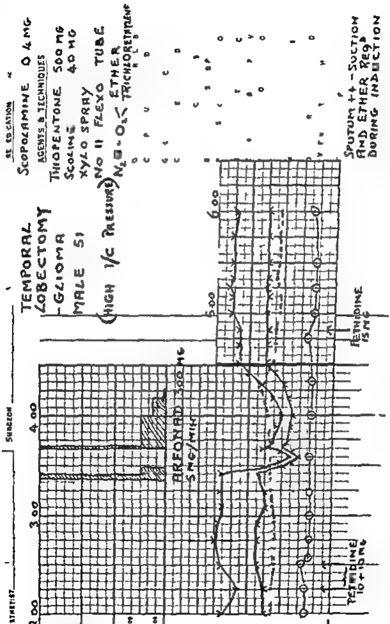

FIG 34 The pulse rate in this case is little affected by trimetaphan Note the use of suction and diethyl ether during induction to remove excessive secretions and relieve bronchospasm

the systolic pressure at no time fell below 70 mm of mercury and was generally at 80 mm of mercury 2 5 g of trimetaphan were given over $3\frac{1}{2}$ hours A second resistant patient was given 2 g in 3 hours and developed oliguria post operatively but recovered after the rapid institution of the Bull[29] regime In this case the systolic pressure did not fall below 90 mm of mercury Although no histological evidence was available, it was felt that as 30% of trimetaphan is excreted unchanged by the kidneys and as the blood pressure had not been below 70 mm of mercury in either case the renal failure might be from drug overdosage or toxicity rather than hypotensive origin Since then the maximum dose of trimetaphan has been set at 1 g [-3] and is never exceeded even in the face of severe resistance We have had no other complications related to hypotensive anæsthesia and it may be mentioned that oliguria and anuria have developed post operatively in neurosurgical cases unrelated to either hypotension or anæsthesia Apnœa following the use of 2 g of trimetaphan in 40 minutes has been reported in a neurosurgical case during hypo thermia and anæsthesia [-4]

Various methods have been tried to overcome resistance without using excessive doses of trimetaphan

(i) The first essential is that the initial rate of dosage should be high to avoid tachyphylaxis

(ii) In the presence of a persistently high pulse rate procaine amide has been recommended during hypotension with hexametho nium bromide [-5] This has been used in similar circumstances during trimetaphan hypotension (Fig 30) Procaine amide 100 mg is given intravenously as a test dose and provided the pulse remains regular the E C G normal and provided there is no precipitous fall in blood pressure a further 400 mg may be given at a rate not exceeding 200 mg per minute This is occasionally but not always helpful

(iii) Positive pressure respiration either assisted or controlled may lower the blood pressure [6] by diminishing venous return to the heart and possibly lowering carbon dioxide tension In spite of our dislike of positive pressure respiration in neurosurgery and its effect on cerebral venous pressure we have resorted to it during resistant cases with occasional success

(iv) The use of suction on the legs to reduce venous return has

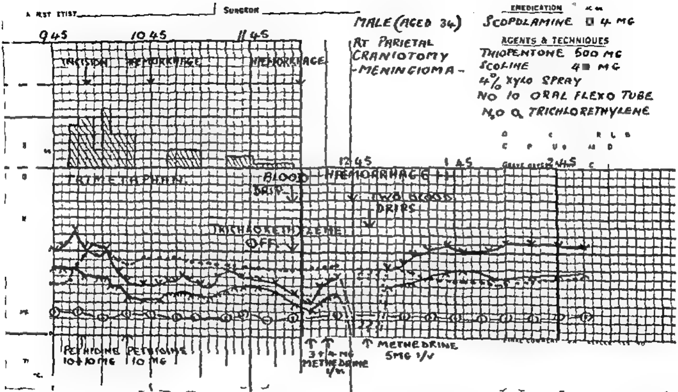

FIG 35 In this case of craniotomy for meningioma severe hæmorrhage occurred in spite of the use of trimetaphan and ■ systolic pressure of 60 mm Hg Note the use of methyl amphetamine to overcome the drug hypotension and rapid blood transfusion to restore the blood volume

[3] Davison M H A (1958) *Brit med Bull* 14, 52
[4] Saunders J W (1952) *Lancet* 1 1286
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[9] Saunders J W (1954) *Lancet* 1, 1156
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[16] Robertson J D Gillies J and Spencer K E V (1957) *Brit J Anæsth* 29, 342
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[1] Zaimis E J (1956) *Wellcome Foundation Symposium on Hypotensive Drugs* p 85 Pergamon Press London
[2] Bull G M Joekes A M and Low K G (1949) *Lancet* 2, 229
[3] Ballantine R I W (1956) *Anæsthesia* 11, 310
[24] McBurrows M Dundee J W Francis I Ll Lipton S and Sedzimir C B (1956) *Anæsthesia* 11, 4
Mason A A and Pelmore J F (1953) *Brit med J* 1 250
[26] Enderby G E H and Pelmore J F (1951) *Lancet* 1, 663
Enderby G E H (1954) *Lancet* 1 185

already been mentioned as has the replacement of induced hypo tension by *positive negative pressure control of the respiration*

(v) Increasing the head up tilt may lower the pressure but must not be overdone even in these resistant cases It has been calculated that the elevated regions are reduced in pressure by 30 mm of mercury for every 15 in of vertical height above heart level [27] Davison[3] points out that the relevant pressure for maintaining the cerebral blood flow in man is not yet known but on the basis of evidence in the monkey the normal is probably between 45 mm and 70 mm of mercury

(vi) For a time, deep ether anæsthesia was induced before bringing the patient into the theatre While maintenance during operation was non explosive with trichlorethylene, the initial vasodilatation achieved with ether before the injection of trimetaphan, did assist the subsequent hypotension However as ether is likely to raise the intracranial pressure and possibly give a less smooth induction it is no longer used except as mentioned to overcome bronchospasm

(vii) With the introduction of halothane it seems likely that resistant cases will be met less frequently This in itself should serve as a further reminder of the potency of halothane and the care with which this drug should be used at all times particularly when com bined with any additional hypotensive agent Using 0 5% halothane and a slight head up tilt the blood pressure may already be low and no further hypotension required If the pressure and operating field are not satisfactory then we think it is safer to add very small amounts of trimetaphan than to try and lower the pressure with increasing concentrations of halothane

We believe that used with great care the advantages gained from *hypotension using trimetaphan in selected cases outweigh* the dangers Unlike Campkin and Inglis [9] we do not believe that it is necessary to use hypothermia whenever hypotension below 80 mm of mercury is required and in fact believe that this introduces an additional hazard

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1 ENDERBY G E H (1958) *Brit med Bull* 14 49
2 LITTLE D M (1956) *Controlled Hypotension in Anæsthesia and Surgery* Thomas Springfield Ill

effects of the vascular spasm that accompanies direct surgical attack and minimize the reaction of brain tissue to trauma It will also allow the induction of a lower level of hypotension for a short period when the aneurysm itself is approached These are our two main indications

We do not use hypothermia in cases of aneurysm not requiring circulatory occlusion and are prepared to lower the blood pressure to 60 mm Hg without it

If excessive hæmorrhage is anticipated in cases of large angiomata and meningiomata hypothermia may be used to protect the cerebral and other vital tissues from the effects of prolonged hypotension

The decrease in cerebral blood flow brain volume intracranial pressure and venous pressure that are said to accompany hypothermia[7] have been mentioned previously (see Chapter 4) but in our experience we have not found the advantages claimed justify the use of the technique in cases of very high intracranial pressure of a non vascular origin or simply to improve operating conditions

The use of hypothermia in non vascular tumours in the region of the hypothalamus and brain stem has been described [8] While we do not use it during the surgery of these cases we believe that in pyrexias of brain stem origin active measures should be taken to reduce the temperature to normal

We regard the following then as indications for hypothermia during operation—

1 Aneurysms (i) Middle cerebral artery
(ii) Anterior communicating artery (When obliteration of the aneurysmal sac or its neck is contemplated)

2 Large angiomata / Large meningiomata } when severe hæmorrhage is expected and when it is desirable to reduce the reaction of nervous tissue to trauma

Technique

This is based on the method described by the Liverpool neuro surgical team[3] which has given a great stimulus to the use of hypothermia in neurosurgery in this country

Chapter 6

HYPOTHERMIA

In 1950 McQuiston[1] introduced the idea of lowering the body temperature during anæsthesia for cardiac surgery, and since then there have been many reports of its successful use in this field

Dundee[2] and his colleagues in 1953 suggested that hypothermia might be indicated during neurosurgical operations and in 1956 he and other workers[3] in Liverpool described a technique used in 50 of these cases

While moderate hypothermia is being superseded in cardiac surgery by the use of cardio respiratory pumps[4] it seems likely that it will continue to find application in neurosurgery[5]

The extent to which hypothermia is employed varies enormously in individual units There are some[3,6] who believe that it should be induced whenever the hypotensive drugs are used, and during operations in the region of the mid brain or hypothalamus while others regard it as an unnecessary procedure We believe that there are indications for hypothermia but that these are limited to relatively few cases

Indications

As Gray[5] has written the principle underlying the use of hypo thermia is to reduce temporarily the oxygen requirements of the vital tissues particularly those of the central nervous system

If the circulation to any part of the brain is to be cut off tempor arily then hypothermia must be used The middle cerebral artery may have to be clipped during operation for an aneurysm of this vessel This has been done for periods ranging between $4\frac{1}{2}$ and $12\frac{3}{4}$ minutes at a rectal temperature of 30 C without any evidence of permanent cerebral damage[3] Hypothermia is also indicated for aneurysms of the anterior communicating artery when a direct approach is being made to ligate the neck of the aneurysmal sac Hypothermia in these cases will protect cerebral tissue from the

Hypothermia

The patient is lifted on to a second trolley on which one large jaconet bolster filled with crushed ice has been placed When lying on this ice, the rest of the patient s body is covered with about fifteen ice bags and a fan turned on Every 10 minutes the bags are moved about and the underlying tissues kneaded and massaged The patient is lifted so that his back may be similarly treated This is important to encourage uniform heat exchange and to avoid very cold pressure points on the back The skin under the ice bags should look pink if it does not or if there is evidence of shivering or the appearance of excessive goose pimples[10] in the absence of a falling temperature, small doses of chlorpromazine 10 mg at a time, are given intravenously Additional chlorpromazine may also be indicated if the temperature is not falling satisfactorily Shivering must be prevented and may be almost imperceptible and only recognized by a quivering of the E C G stylus Dundee and King[11] stressing that the body s reaction to cold must be obtunded mentions that invisible shivering may be recognized as a generalized muscular hypertonus He also points out that both the pulse rate and blood pressure may rise as a result of shivering

The E C G tracing is watched continuously and someone is always ready to do a thoracotomy and start cardiac massage if ventricular fibrillation should develop Massage must be continued until the temperature of the heart is raised and a normal beat restored

The temperature readings are noted every 10 minutes and while originally the rectal temperature was recorded alone now the œsophageal reading is the principal guide When this has reached 33 0°C (91 4°F) the patient is removed from the ice and dried In our series of cases the average time necessary to reach this temperature has been 45 minutes The shortest time was 15 minutes in a patient whose temperature had already fallen to 35°C (95°F) following premedication and the longest 80 minutes

A blanket through which cold or warm water can be circulated is already in position on the operating table and the patient is transferred to the theatre and placed on this with sorbo pads under the scapulæ buttocks and heels

Premedication

In adults this is with chlorpromazine, promethazine and pethidine, up to 50 mg of each by deep intramuscular injection 2 hours before anæsthesia Obviously the dosage must be regulated by the size and general condition of the patient The pethidine and promethazine are omitted altogether from the premedication if the patient is unconscious before operation In children the promethazine is not considered essential and the doses of chlorpromazine and pethidine are appropriately reduced

All the patient s clothes and bedding except for one sheet are removed half an hour after the premedication, so that when anæsthesia is induced the body temperature has usually fallen by one or two degrees Fahrenheit

Induction of anæsthesia

When reaching the cooled anæsthetic room the patients are usually sleepy but will respond to questions Anæsthesia is induced with a small dose of 2½% thiopentone followed by suxamethonium in the usual way After spraying and intubation the patient is settled with nitrous oxide oxygen and trichlorethylene diethyl ether or halothane Halothane has been advocated[6] for facilitating the induction of hypothermia and because of its vaso dilator properties may obviate the necessity for promethazine premedication

The pharyngeal and œsophageal leads of an electric thermometer and the rectal lead of a mercury thermometer are inserted It has been found an advantage to use both methods of recording the temperature as a more accurate overall picture may then be obtained The electrocardiographic and sphygmomanometer leads are applied, and intravenous drip of 4 3% dextrose in 0 18% saline is inserted into one foot to run very slowly and a Mitchell needle into the other It has been suggested[9] that dextrose should be used in a dilute 2 5% solution as glucose is metabolized slowly during hypothermia

Once satisfactory anæsthesia has been established and initial recordings of temperature blood pressure E C G pulse and respiration rates have been made then the induction of hypothermia can begin

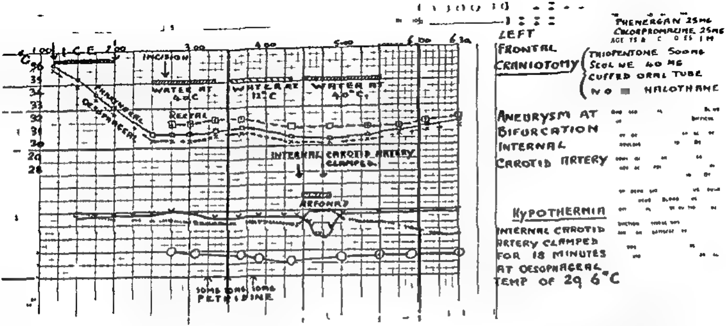


FIG 36 Anæsthetic chart of a patient having a frontal craniotomy for ligation of an aneurysm at the bifurcation of the left internal carotid artery Note the use of water at varying temperatures circulating through a blanket to control the final temperature level

An after drop in temperature always follows removal from the ice and the average in our cases has been 3 8°C (6 8°F) It is our aim to have the temperature at 30°C (86°F) during the critical period of the operation, and although the blanket on the table will not produce dramatic changes in temperature it does help in stabilizing the patient at the required level If for example a rapid after drop occurs and the temperature is obviously going to fall too far then we are convinced that by circulating water through the blanket at 40°C (104°F) the drop in temperature can be stopped before dangerous levels are reached (Fig 36) The temperature of the water must never exceed 42°C (107 6°F) as burns of the cold skin may be caused so easily As a safeguard a thermometer is kept in contact with the blanket coils as well as in the water The sorbo pads prevent the possibility of burns in pressure areas where the circulation may be stagnating Cold water may be circulated if it seems that the after drop is going to be less than usual and the final temperature too high We have found the average time taken for the temperature to reach its lowest level to be 113 minutes but this figure includes the cases recorded before the use of a blanket, and so could probably be reduced

At 30°C (86°F) the pulse is almost always slow and may be between 40 and 50 beats per minute The blood pressure is variable and not necessarily low We have had no difficulty in auscultating the blood pressure in neurosurgical cases and yet in thoracic cases not premedicated with chlorpromazine or promethazine it is usual for this to become unrecordable very early in hypothermia by the surface method This may be due partly to the use of controlled respiration in thoracic cases and partly to the abnormal cardiovascular condition

Nitrous oxide and oxygen alone are usually sufficient to maintain anæsthesia once the temperature is low and spontaneous respiration is generally quiet and slow

Rewarming

After operation the patients are returned to bed and covered with blankets in the usual way No active measures are taken to rewarm the patients unless as mentioned the temperature is falling too far

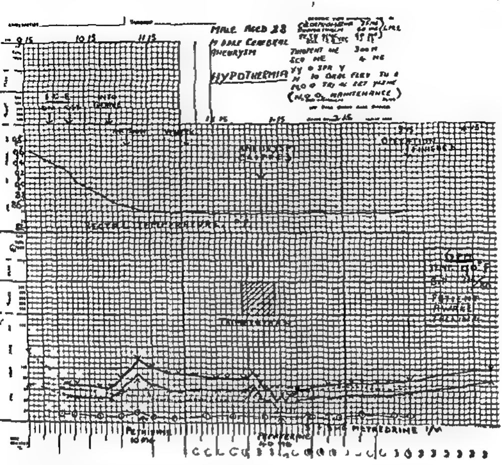


FIG 37 Anæsthetic chart of a patient undergoing ligation of a middle cerebral aneurysm with hypothermia and hypotension Very little active cooling was required in this case Note the use of papaverine to reduce cerebral vascular spasm unrelieved by hypothermia or trimetaphan

falling temperature which makes reversal of the spasm more difficult The net result being that there is no real protection by cold in the region where damage is most severe during the first few critical days following subarachnoid hæmorrhage

The electrocardiogram

The E C G changes during hypothermia are best seen in lead II and may show a widening of the Q R S complex and lengthening

The whole process from the induction of hypothermia to return of normal temperature usually takes about 12 hours

Sometimes if cerebral œdema is anticipated in the post operative period or pyrexia from disturbance of the heat regulating centre then hypothermia is continued This is a simple matter only requiring the removal of blankets the use of an electric fan and small doses of chlorpromazine and possibly pethidine An after rise in temperature is often seen following the return to normal temperature but does not usually persist

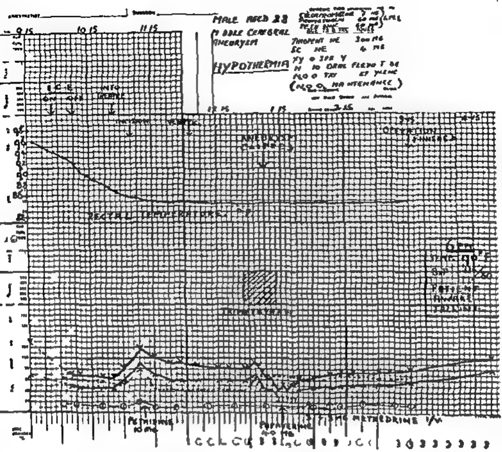
It has been shown that the patient s general condition may deteriorate during the later stages of rewarming particularly during the first 24 hours The suggestion has been made that this may be due to the rapid restoration of body temperature before the circulation is able to supply sufficient oxygen for normothermic tissues [1°] For this reason slow rewarming or even continued hypothermia may be advantageous particularly when the peripheral circulation is poor or the possibility of cerebral ischæmia exists

While consciousness usually returns at a surprisingly low temperature if at the end of the operation it seems likely that the protective reflexes of the larynx and pharynx are going to remain depressed it is advisable to leave a cuffed endotracheal tube in position for the first few hours to maintain a clear airway In any neurosurgical cases with persistent coma the possibility of tracheostomy must be considered

Hypotension

Trimetaphan has been used during hypothermia to provide hypotension for short periods in the majority of cases of aneurysm The relatively large doses required have been mentioned in Chapter 5 With the temperature at 30 C (86°F) it has been considered justifiable to lower the systolic blood pressure to below 60 mm Hg for a few minutes during the critical stage of operations on aneurysms and this has been done without ill effect

Neither hypothermia nor trimetaphan prevent the vascular spasm that is present during the surgery of aneurysms and the intravenous injection of papaverine 40 mg may still be required (Fig 37) Brown[13] believes that there is an aggravation of arterial spasm with



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The electrocardiogram

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of the P R and S T intervals (Fig 38) S–T depression and inversion of the T wave may sometimes occur The presence of an Osborne wave immediately following the Q R S and giving the R S a notched appearance is said to represent a fall in arterial pH [14] Elmsley Smith[15] refers to this as junction deflexion or J deflexion and has

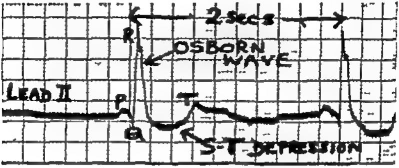

FIG 38 E C G showing changes during hypothermia

shown the E C G pattern to be pathognomonic of accidental hypothermia

Ventricular tachycardia and ventricular fibrillation must be immediately recognized These are shown in Figs 39 and 40 in tracings made during cardiac surgery

Ventricular fibrillation

This is the greatest danger of deep hypothermia but is less likely at temperatures above 28°C (82 4 F) Provided that the temperature is not allowed to fall below 30°C (86°F) fibrillation should not occur in non thoracic cases This is the optimum temperature for neuro surgical work and ventricular fibrillation has not developed in any of our small series of cases Gray[16] has reported that except after intracardiac manipulation no case of ventricular fibrillation has occurred in a series of over 250 patients cooled by the surface method is his department None of the 180 neurosurgical cases included in his series had artificial ventilation and similarly in our own patients spontaneous respiration has been the rule This is of interest as the use of hyperventilation to reduce the tendency to ventricular fibrillation has been advocated [1, 10] The importance of

maintaining a steady level of pH in hypothermic patients was stressed in 1950[19] and it seems likely as Gray suspects[16] that it is steady ventilation and the avoidance of sudden changes that matters At the other extreme Delorme[1-] mentions the work of Lewis and Niazi [8] and the use of 5–10% carbon dioxide in the anæsthetic mixture during cooling to prevent the onset of fibrillation

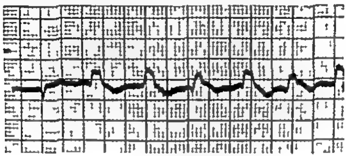

FIG 39 E C G of ventricular tachycardia during cardiac surgery

FIG 40 E C G showing ventricular fibrillation during cardiac surgery (These tracings supplied by courtesy of Dr B G Wells)

While ventricular fibrillation fortunately seems to be an unlikely complication in neurosurgical hypothermia there must be no relaxation of vigilance on the part of the anæsthetist The E C G must be observed continuously and the means for thoracotomy cardiac massage and defibrillation always at hand

Blood coagulation and transfusion

The coagulation time is increased by lowering the body temperature but we have not experienced trouble from prolonged oozing or

of the P R and S T intervals (Fig 38) S–T depression and inversion of the T wave may sometimes occur The presence of an Osborne wave immediately following the Q R S and giving the R S a notched appearance is said to represent a fall in arterial pH [14] Elmsley Smith[15] refers to this as junction deflexion or J deflexion and has

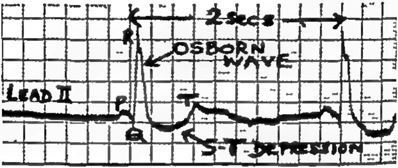

FIG 38 E C G showing changes during hypothermia

shown the E C G pattern to be pathognomonic of accidental hypothermia

Ventricular tachycardia and ventricular fibrillation must be immediately recognized These are shown in Figs 39 and 40 in tracings made during cardiac surgery

Ventricular fibrillation

This is the greatest danger of deep hypothermia but is less likely at temperatures above 28°C (82 4°F) Provided that the temperature is not allowed to fall below 30°C (86°F) fibrillation should not occur in non thoracic cases This is the optimum temperature for neuro surgical work and ventricular fibrillation has not developed in any of our small series of cases Gray[16] has reported that except after intracardiac manipulation no case of ventricular fibrillation has occurred in a series of over 250 patients cooled by the surface method is his department None of the 180 neurosurgical cases included in his series had artificial ventilation and similarly in our own patients spontaneous respiration has been the rule This is of interest as the use of hyperventilation to reduce the tendency to ventricular fibrillation has been advocated [17 18] The importance of

post operative bleeding either in short or prolonged hypothermia It has been suggested[16] that in the latter low temperatures should be avoided and the coagulation time watched carefully

There is a possibility of citrate intoxication from rapid blood transfusion particularly in hypothermic patients [21] for at a temperature of 28–29°C (82 4–84 2°F) the metabolic destruction of citrate has been shown to be reduced by 30–40% If rapid transfusion is required during hypothermia then 1 8 ml of a 10% solution of calcium chloride should be added to each 500 ml of blood

Delorme[1] mentions that blood should be given with care during hypothermia because of the decrease in vascular capacity and the known congestion of liver and lung In our experience, by combining a hypotensive agent with hypothermia when excessive hæmorrhage is expected blood transfusion has seldom been required However this is not to suggest that the combination of these techniques precludes the occurrence of severe hæmorrhage

Blood used for transfusion during hypothermia should be less than four days old otherwise it may have too high a potassium content Howland mentions that increased potassium decreased body temperature decreased pH and a shift of the oxygen association to the left may contribute to cardiac arrhythmia He also discusses the question of citrate intoxication

The temperature of the infused solution should be approximately the same as that of the patient

Complications

In our series of patients having hypothermia during neurosurgical operations there have been no complications attributable to the lowered temperature either during or after operation although early in our experience the temperature sometimes fell lower than we intended We believe that slow cooling and gradual rewarming from a minimum temperature of 30°C (86°F) is a safe procedure during neurosurgical operations and in fact has increased the safety of the more hazardous of these This assumes perfect anæsthesia the use of the minimum of anæsthetic drugs and continuous E C G monitoring Spontaneous respiration is allowed and thus the advantages that we believe this has in neurosurgery are retained

Therapeutic Hypothermia

The use of hypothermia in head injuries [3, 4, 5] and as a therapeutic measure in massive cerebral hæmorrhage [6, 7] has been reported The method has been used in the Neurosurgical Department of St Bartholomew s Hospital in similar cases in the hope that by pro tecting the brain tissue from the ischæmic pressure effects of cerebral œdema, and by reducing the cerebral volume it would aid recovery

One case in which hypothermia appeared to be of value is of interest

Case report

While awaiting operation for a left middle cerebral aneurysm a male patient of 44 years suffered a recurrent hæmorrhage He became comatose with periods of apnœa, and had decerebrate rigidity with extensor spasms Two hours after the hæmorrhage hypothermia was induced with chlorpromazine 12 4 mg pethidine 12 5 mg and phenergan 12 5 mg given by intravenous injection, and the application of ice bags The trachea was intubated The temperature was reduced to 31 1°C (88°F) and the decerebrate rigidity passed the pupils became reactive the respiration regular and consciousness returned

Eighteen hours after the hæmorrhage a left frontal craniotomy was performed under general anæsthesia with trimetaphan hypo tension and with the hypothermia maintained During surgery the middle cerebral artery was temporarily occluded proximal to the aneurysm as this ruptured

Normal temperature was allowed to return after operation and the patient was discharged alert and orientated with a persistent nominal dysphasia as the only neurological deficit

The use of prolonged hypothermia in other cases has not been of convincing value One patient with a fissured fracture of the skull and cerebral contusion was cooled for one period of six days and then following tracheostomy and burr hole exploration for a second period of three weeks There was little change in the neurological picture and the patient died The body temperature was maintained

as near 32 2°C (90°F) as possible over this long period Post mortem examination showed no change referable to the hypothermia In this type of case with prolonged cooling there may be advantages in allowing the temperature to rise at regular intervals

Tracheostomy must be performed if the airway cannot be kept clear with good nursing care alone and adequate ventilation ensured *Feeding is by the intravenous route or stomach tube and* the correct balance of electrolytes must be maintained

The blood pressure falls fairly soon after the induction of hypothermia in these deeply comatose patients and it may be difficult to raise this with the usual vasopressor drugs This seems to be one of the main difficulties during prolonged cooling

From our small experience of prolonged hypothermia and a study of the reports of others we are not yet convinced of its value The indications for its use are not clear cut at present Sedzimir and his colleagues [6] suggest that two groups of cases may lend themselves to this form of therapy namely—

1 Intracranial ischæmic lesions

2 Pyrexias of hypothalamic and brain stem origin

We believe that a raised temperature in these cases must be reduced to normal and the possibility of hypothermia considered

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Chapter 7

INDIVIDUAL OPERATIONS I
THE BRAIN

WHILE the standard anæsthetic technique already described remains the same in most neurosurgical cases there are certain features of particular operations that require elaboration. As many of these are for tumours, a simple classification[1] of the common cerebral tumours is given before discussion of the individual operations in each region

Common tumours in childhood and their situation—

Astrocytoma (commonly cystic) Cerebellum
Medulloblastoma Cerebellar vermis and IVth ventricle
Craniopharingioma Suprasellar region
Ependymoma IVth IIIrd or lateral ventricles
Pinealoma Posterior end of IIIrd ventricle
Spongioblastoma polare Brain stem or optic chiasma

Common tumours in adult life and their preferential sites—

Glioma Group Cerebral hemisphere any location
Meningioma Along sagittal sinus sylvian fissure olfactory groove and convexity of cerebral hemispheres
Pituitary adenoma, Craniopharingioma } Sella turcica
Neurinoma VIIIth nerve in cerebello pontine angle
Hæmangioblastoma Cerebellum
Metastases Anywhere and often multiple

Frontal Region

Whilst being well away from the vital medullary centres it is not generally realized that stimulation of cortical areas on the orbital surface of the frontal lobe produces alteration in heart rate blood pressure and breathing[2] Changes in respiration may be seen during operations which necessitate retraction of the frontal lobe but

changes in blood pressure and pulse rate have not been apparent in our cases

Tumours

Gliomata The effects these produce are both local and general but it is the general rise in intracranial pressure that is most likely to concern the anæsthetist

Tumours of vascular origin These will require the use of hypo tensive and possibly hypothermic techniques as already described

Meningiomata These extra cerebral tumours which are intimately attached to the dura arise from cells of the arachnoid In the frontal region they may be found on the under surface of the brain in relation to the olfactory groove They may be parasagittal from the superior sagittal sinus or falx or suprasellar in the region of the tuberculum sellæ Hæmorrhage is likely to occur in relation to them, and to provide the main anæsthetic problem Hæmorrhage may be expected in the early stages of the operation as these tumours may erode bone and derive a considerable amount of their blood supply from dural vessels

Pituitary tumours From the surgical viewpoint these are either chromophobe or eosinophil adenomata Chromophobe tumours frequently cause anterior lobe deficiency Eosinophil adenomata at first show hyperfunction with giantism[3] and acromegaly though later often at the time of operation hypopituitarism may be present These patients will therefore require particular care during and after operation

These tumours are approached by the frontal route and may be difficult to visualize without retraction and attendant effects on respiration A low brain tension in these circumstances will facilitate the surgeon s work and reduce trauma to the patient The methods available for achieving this have been mentioned

Hunter[4] classifying the disturbances of vital function that may occur during neurosurgery has described how the hypothalamic centres may be damaged during the removal of Rathke cysts derived from the cranio pharyngeal pouch suprasellar and olfactory groove meningiomata There may be an initial fall in blood pressure followed by a rise in respiratory and pulse rates Post operatively

coma and hyperpyrexia may develop The temperature must be lowered to normal by cooling and attempts made to maintain the blood pressure with vasopressor drugs

Fractures

The frontal sinuses may be involved in fractures in this region and the possibility of blood and C S F entering the upper respiratory tract and being aspirated must be remembered In the operation for repair of cranio nasal fistula for example the pharynx must be packed following intubation The use of packs when a low frontal flap is raised has been mentioned in Chapter 3

Leucotomy

The frontal lobes are linked with the thalamus and hypothalamus and thus to the autonomic nervous system In the operation of leucotomy selected fibres of the frontothalamic tract are divided and alterations in respiration and blood pressure may occur

It is important to remember that before operation these patients may have been having large doses of sedative and tranquillizing drugs The effect of premedication and anæsthesia superimposed on these must be anticipated If necessary the dosage of drugs such as chlorpromazine and paraldehyde should be decreased some days before operation Although these patients may be very restless before induction and even require some restraining before intra venous injection can be made they are subsequently often sensitive to respiratory depressant drugs

Hypophysectomy

In cases of bone metastases from hormone dependent carcinoma of the breast and prostate hypophysectomy may be of value It is now generally believed that progressive cellular multiplication in some cancers of the human breast is strictly conditioned by an adequate supply of an anterior pituitary hormone [5] It is suggested that this mammotrophic hormone is prolactin Urine from normal premenopausal women has been found to contain this mammo trophic substance It is not found in the urine after hypophy sectomy [5 6]

These patients require special preparation as follows 200 mg cortisone acetate is given daily by intramuscular injection for 2 days before operation and continued for 5 days after On the 6th and 7th days the dose is reduced to 150 mg intramuscularly once a day, or 50 mg by mouth 8 hourly On the 8th and 9th days 100 mg is given intramuscularly each day or 50 mg by mouth 12 hourly Subsequent maintenance is then reduced to 25 mg by mouth daily

If bilateral adrenalectomy has already been performed then in addition an intravenous drip of dextrose saline with 100 mg hydro cortisone hemisuccinate is required during the operation and possibly afterwards

These patients are often in poor condition and likely to be anæmic The hæmoglobin percentage is estimated and blood transfusion given before or during operation as indicated

The bone metastases usually give rise to severe pain and the patients may have been taking large doses of analgesic drugs and chlorpromazine Scanlon has emphasized that anæsthetic drugs must be used with caution in patients on long term chlorpromazine therapy There is the possibility of fractures occurring in bones weakened by secondary deposits and great care is taken when lifting and positioning these patients

Originally we used hypotensive drugs during operation [8] and others have suggested the use of spinal drainage and hypothermia [9] We now consider that these techniques are unnecessary and find the simple general technique already described is entirely satisfactory

In the immediate post operative period these patients are usually in better condition than would be expected and very few analgesic drugs are required Hypotension may develop but responds to small doses of methylamphetamine Thirst is a common early complaint and a much greater fluid output than input gives early evidence of diabetes insipidus We have seen neither hypoglycæmic crises nor hypopituitary coma

Aneurysms

Aneurysms of both the middle cerebral and anterior communi cating arteries are approached by frontal craniotomy The use of hypotension and hypothermia in these cases has been discussed

Abscesses

These may develop in the frontal region particularly following infection of the ethmoid and frontal sinuses, and may be associated with compound fractures Cerebral œdema accompanying the abscess will result in a raised intracranial pressure, and the danger of coning must be remembered during the induction and subsequent maintenance of anæsthesia

Temporal Region

Tumours

Gliomata These are common in the temporal region As they and accompanying cerebral œdema occupy more space within the cranium serious abnormalities will result extending from field defects and personality changes to brain stem displacement Herniation of the uncus at the anterior end of the hippocampal gyrus will occur as supratentorial pressure rises and the third cranial nerve may become compressed and the pupil dilate Mid brain function may become impaired with an altered level of consciousness hyperthermia and respiratory disturbances The effects of these changes on the anæsthetic technique will be obvious

Meningiomata These may develop in this region and in addition to their local effects give rise to changes characteristic of raised intracranial pressure

Abscesses

Middle ear or mastoid infection may give rise to abscesses in the temporal lobe and cause a rise in intracranial pressure Evacuation and ultimately excision of these will require temporal craniotomy

Section of Vth sensory root

Whilst the cause of trigeminal neuralgia remains unknown the attacks of pain that arise in one or more divisions of the trigeminal nerve may be very severe

The role of the anæsthetist in the treatment of tic douloureux and a method of alcohol injection has been described by Rollason [10] In many cases it is necessary for the neurosurgeon to divide the sensory

root under general anæsthesia This is done with the patient in a steeply reversed Trendelenburg position with the head fully flexed and held in a special head rest (Fig 41) The use of this position minimizes venous oozing lowers intracranial tension and is usually accompanied by good operating conditions

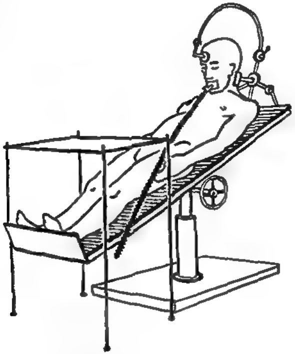

FIG 41 Section of Vth sensory root Drawing to show the position used for this operation

The patients are often elderly and postural hypotension may occur initially (see Fig 4) The tilt of the table must be reduced and vasopressor drugs given if required In this position there is the possibility of air embolism a complication that will be dealt with later

These patients are intubated in the usual way using a large flexo metallic tube and the catheter mount is attached to the vertical limb of the suction union In this way full head flexion is possible without the danger of any part of the anæsthetic tubing becoming kinked Much surgical stimulation is inevitable in this operation The dura

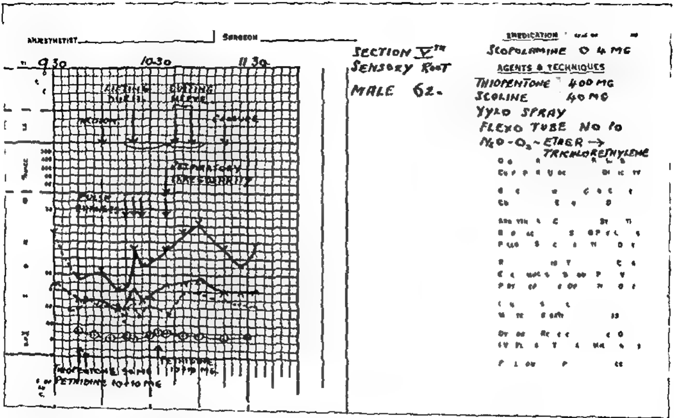

Fig 42 Section of Vth sensory root Typical anæsthetic chart This shows the initial fall in blood pressure with the steep reverse Trendelenberg position the rise that accompanies the stimulating part of the operation and the secondary fall during closure

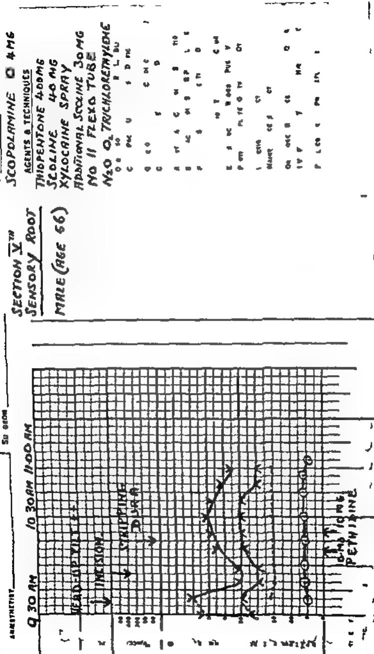

FIG 43 Section of Vth sensory root Another typical anæsthetic chart

has to be separated from the floor of the middle cranial fossa in relation to the middle meningeal artery and nervus spinosus The anæsthetic charts usually have a typical appearance (Figs 42 43) and show a rise in blood pressure during approach to Meckel s cave

(*a*)

(*b*)

(*c*)

FIG 44*a* *b* and *c* E C G changes in Lead 2 from surgical stimulation during approach to trigeminal ganglion for section of Vth sensory root These were unrelated to trichlorethylene and obviously due to the surgical stimulation

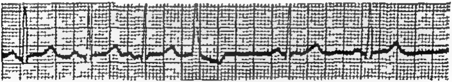

FIG 45 Another E C G change in Lead 2 during section of Vth sensory root due to surgical stimulation

Tacchypnœa may develop and anæsthesia have to be deepened while at the same time the danger of depressant drugs in old people in this position must not be forgotten We have been interested to see E C G changes produced by the surgical stimulation (Figs 44*a* *b* and *c* and 45) Similar changes are not seen during division of the

spinothalamic tracts and possibly illustrate the difference in sensitivity of the first and second neurone

When all the rootlets are divided corneal sensation is lost and the patient must wear an eye shield after operation but this is only a temporary measure if the ophthalmic fibres are spared

Sub occipital Region

The posterior fossa approach used for operations in this region requires detailed description

One of three positions may be used—

(*a*) Sitting
(*b*) Prone
(*c*) Lateral

(*a*) **Sitting position** The head is either supported by a special head rest or by calipers and wire pulley The latter system used at St Bartholomew s Hospital is very satisfactory and is illustrated in Fig 46

The head is held in a vertical position by the wire coming from the winch at the foot of the table The tilt of the table can be altered without the degree of head flexion being changed and the head brought below heart level This is done during closure to raise the venous and systolic blood pressure so that any latent sources of hæmorrhage are disclosed and can be dealt with and is also of value if the patient s condition should deteriorate and hypotension develop The apparatus is simple and can be used with various operating tables

In this position bleeding is minimized and there are few respiratory problems resulting from raised intracranial pressure and associated brain stem ischæmia

The disadvantages are firstly that all patients and particularly the elderly in this steep head up position are sensitive to drugs with respiratory depressant or hypotensive properties Thiopentone pethidine halothane and similar drugs must be used with great caution and of the inhalation anæsthetics our own preference is for trichlorethylene

Secondly purely postural hypotension may occur and blood loss

be poorly tolerated Provided that the state of the circulation is carefully watched and adequately maintained by reducing the tilt of the table the use of vasopressor drugs and blood replacement as required then trouble should not develop

Thirdly there is the possibility of air embolism

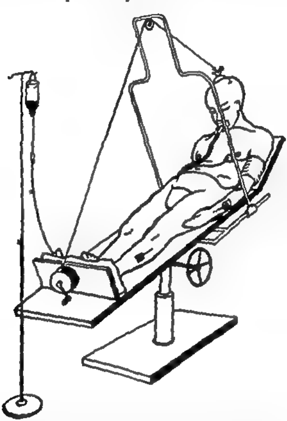

FIG 46 Posterior fossa exploration This shows the position used for this operation The head is flexed and supported by a wire which runs from calipers in the head to a winch at the foot-end of the table

(*b*) **Prone position** This is used by some neurosurgeons but is not accompanied by a reduced intracranial pressure respiratory difficulties are more likely and venous oozing may be increased

(*c*) **Lateral position** In the severely ill both the previous positions may be poorly tolerated and it has been found an advantage on

several occasions to use the lateral position with the head flexed and rotated Although access is not as good the general disturbance in these critical cases is less

It may be mentioned here that the lateral position is sometimes used when craniotomy is performed for evacuation of subdural hæmatoma This allows lumbar puncture to be performed during the operation and saline to be injected intrathecally to raise the C S F pressure following evacuation (Fig 47)

Air embolism

In the sitting and steeply reversed Trendelenburg positions with a low venous pressure and with either a physiological or artificial negative phase in the respiratory cycle, large quantities of air may be sucked through an open vein into the right ventricle The sub occipital venous plexus is a likely site for the entry of air as are the mastoid emissaries and lateral sinus

Experiments with dogs[11] have shown that the right auricle and ventricle dilate and that ischæmia may develop in relation to the anterior descending branch of the left coronary artery The air may become lodged as a bubble in the pulmonary conus but the outflow cleared by turning the dog on to the left side Five cases of air embolism in the sitting position were reported by Hamby and Terry[1] and in one of these turning the patient into the left lateral position prevented a fatal outcome Another successful outcome has been reported[18] with the suggestion that although the possibility of air embolism is enhanced in the sitting position the anatomical relationships of the pulmonary ostium to the rest of the ventricle favour the expulsion of the air bubble into the pulmonary capillaries It was also suggested that intensive pumping of the breathing bag and the consequent pulmonary pressure changes aided evacuation of the air in this case

If air embolism does occur certain characteristic signs may be seen The patient may cough or make bucking movements and then stop breathing giving the impression of being too light and breath holding The pulse becomes irregular and the E C G may show evidence of myocardial ischæmia and right ventricular conduction defects The blood pressure falls a mill wheel murmur may be

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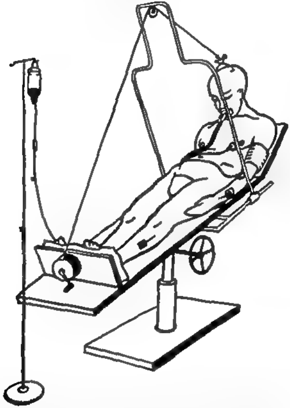

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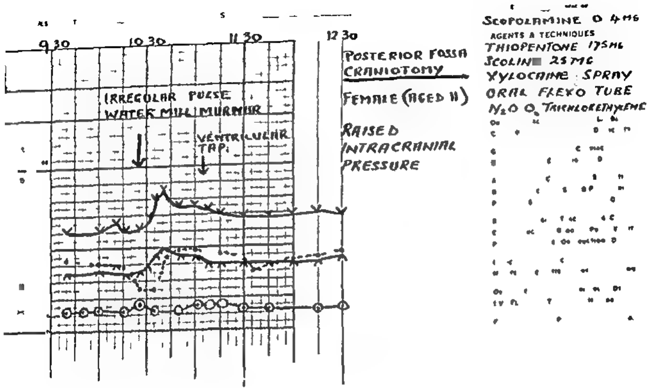

Fig 48 Posterior fossa craniotomy Anesthetic chart showing the point at which a mill wheel murmur was heard giving evidence of a small air embolus

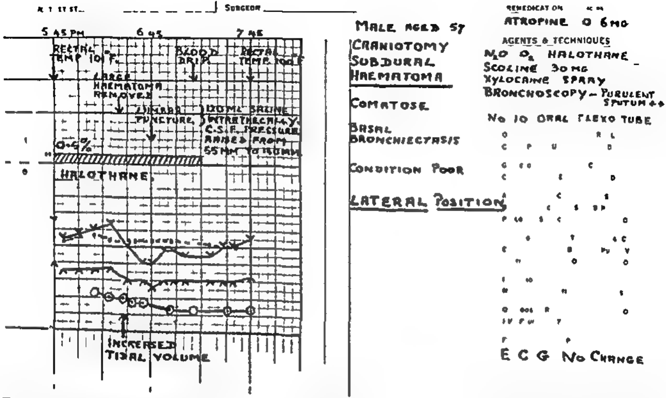

FIG 47 Anæsthetic chart of a male patient of 57 years undergoing craniotomy in the lateral position for evacuation of a subdural hæmatoma He was comatose with a temperature of 101 F and had basal bronchiectasis No thiopentone was used Bronchoscopy was performed at the beginning and end of the operation His general condition improved immediately the hæmatoma was evacuated The intrathecal pressure was raised from 55 mm to 140 mm of C S F *following* decompression by the injection of 120 ml normal saline into the lumbar subarachnoid space

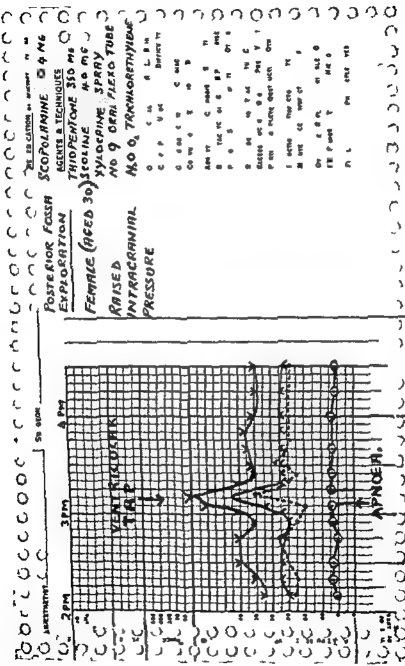

FIG 49 Posterior fossa craniotomy in a woman aged 39 with a raised intracranial pressure Anesthetic chart showing a period of apnœa with raised blood pressure and pulse rate relieved by tapping the ventricles

heard and the heart fail We have seen one fatal case of air embolism in which the first sign was this appearance of the anæsthetic being too light On another occasion, irregular respiration and pulse rhythm suddenly developed and the characteristic mill wheel murmur was heard for a few seconds before normal sounds returned (Fig 48) A spontaneous recovery followed It is probable that small amounts of air enter the circulation in this and other head up positions more commonly than is generally realized

Certain precautions taken as a routine during anæsthesia for posterior fossa explorations will reduce the possibility of air embolism

1 Avoid coughing hyperventilation and any increase in the normal negative intrathoracic pressure

2 Perform jugular compression at regular intervals when the danger is present, to raise the venous pressure

3 Have a sphygmomanometer E C G machine and precordial stethoscope attached to every patient and observe the state of the cardiovascular system continuously

4 Assume that any unexplained change in blood pressure, pulse or respiration is due to air entering the circulation until the converse has been proved by the presence of venous bleeding on jugular compression

If air embolus does occur then the patient must be turned into the left lateral position while the lungs are vigorously inflated with oxygen If the circulation is not immediately restored then cardiac massage is performed through the left chest A successful outcome depends on speed in recognizing and treating this complication and it should not be regarded as necessarily fatal

Disturbances of vital functions in posterior fossa explorations

It is in patients with space occupying lesions in the posterior fossa that disturbances of vital function are most likely to arise

Hunter[1] considers that a rising pulse rate is the commonest sign of a rising intracranial pressure occurring in cerebellar tumours and where there is obstruction to C S F pathways He says that when the pulse rate rises to 140 in an adult or 160 in a child with a cere bellar tumour then ventricular puncture is required We have found

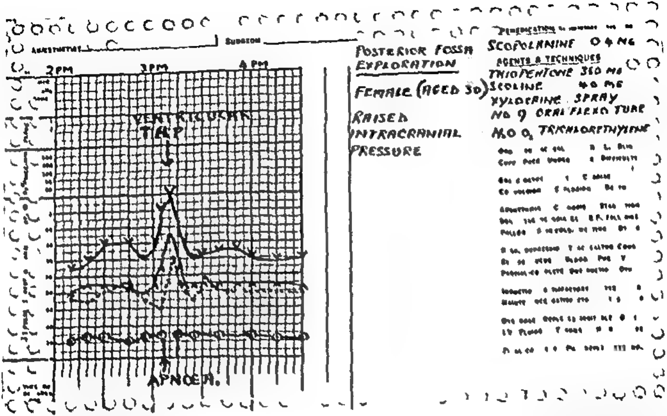

FIG. 49 Posterior fossa craniotomy in a woman aged 39 with a raised intracranial pressure. Anaesthetic chart showing a period of apnoea with raised blood pressure and pulse rate relieved by tapping the ventricles

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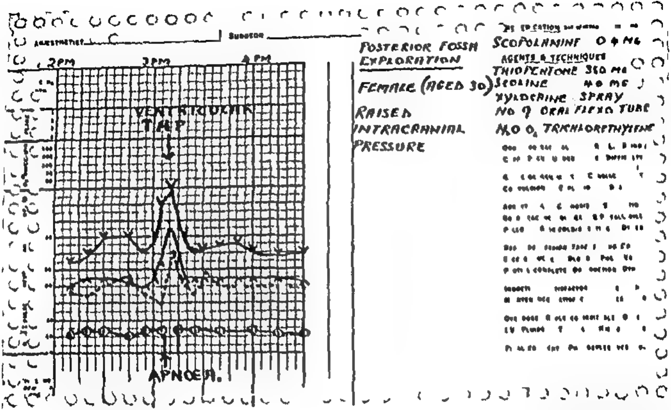

FIG. 49 Posterior fossa craniotomy in a woman aged 30 with a raised intracranial pressure. Anæsthetic chart showing a period of apnoea with raised blood pressure and pulse rate relieved by tapping the ventricles

respiratory changes to be the most obvious The pattern of respiration alters and it may become irregular and shallow Bradypnœa will often occur followed by apnœa Following ventricular tap normal respiration will return at once in most cases (Fig 49) When the disturbance is due to surgical manipulation then a different approach to the tumour may be necessary The respiratory changes are often accompanied by bradycardia and a rising blood pressure

Whatever the sequence of events we must stress once more that it is the anæsthetist s job to recognize them and their cause and to inform the surgeon for failure to do this may have very serious consequences

Following surgery close to the brain stem reactionary œdema may develop and give rise to disturbances in the post operative period with Cushing s triad of bradycardia, bradypnœa and a rising systolic with falling diastolic pressure The level of consciousness may also be altered

Tumours

Medulloblastomata are rapidly growing cellular tumours which occur in children Astrocytomata and more rarely ependiomata and spongioblastomata also develop in this region and their removal may be associated with the disturbances already discussed

Acoustic nerve tumour This is a neurinoma in connection with the sheath of the auditory nerve It lies close to the facial nerve and ultimately with the cerebellum IXth Xth XIth and XIIth cranial nerves Its close association with these structures and particularly the brain stem may give rise to abnormal respiratory and cardiovascular patterns We have seen Cheyne Stokes respiration and ventricular ectopic beats occurring together and quite definitely related to surgical dissection close to the brain stem (Fig 50) The operations are prolonged but require particular vigilance from the anæsthetist

Temporal lobe herniation may follow decompression from preliminary evacuation of the interior of the encapsulated tumour [14]

Facial paralysis will follow the removal of an acoustic neurinoma adherent to the facial nerve and an anastomosis of the facial and

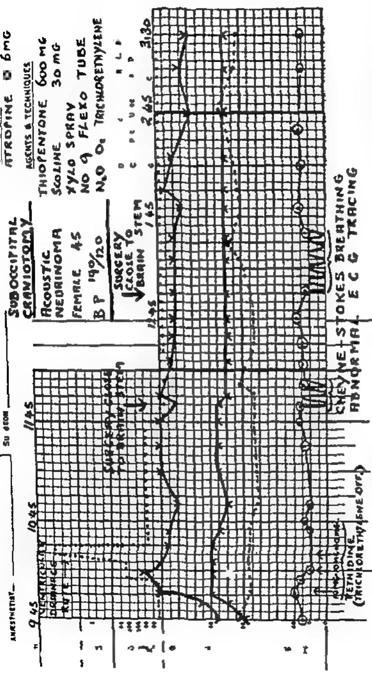

FIG 50 Posterior fossa craniotomy for acoustic neurinoma in a woman aged 45 years Anesthetic chart showing the development of Cheyne Stokes respiration during surgery close to the brain stem Ventricular ectopic beats appeared on the E C G at the same time

hypoglossal nerves be required at a later date Tarsorrhaphy is performed pre operatively

Aqueduct obstruction

Torkildsen's operation The posterior fossa approach is used in this operation to by pass obstruction in the IIIrd ventricle or aqueduct of sylvius A polyvinyl catheter is passed into one lateral ventricle through a burr hole in the skull and then passed down over the exposed cerebellum into the cisterna magna Patients requiring this operation will often be children will have a very high cranial pressure and therefore will be likely to exhibit medullary dysfunction (see Fig 25)

Abscesses

These are likely to arise as in the temporal lobe from middle ear and mastoid infection

Electroencephalography in Neurosurgical Anæsthesia

We are grateful to Dr A J H Hewer of the Middlesex Hospital for the following notes on the uses of electroencephalography during neurosurgical anæsthesia

He believes that the two main applications in this field are—

(i) For determining the exact depth of anæsthesia particularly when this is very light and in maintaining a constant anæsthetic level

(ii) As an aid in the assessment of the condition of a limited area of cerebral cortex during surgery especially when the blood supply to that area is involved

In the first application it is sometimes very valuable to be able to maintain a very constant level of anæsthesia during the surgery of the brain stem or of any other part of the brain when the blood pressure is very low or when there is some reason to expect that ischæmia of the cerebral cortex may supervene Other vital functions such as the heart rate blood pressure and respiration may give a valuable index of serious changes taking place if it can be shown that these are in no way related to a change in the anæsthetic level

This can be a great help in the recovery period also since if the

level of anæsthesia is known to be very light and yet there is a delay in return to consciousness it probably indicates the presence of some intracerebral complication

In determining the level of anæsthesia from the E E G there is a characteristic change with each level of anæsthesia although certain drugs such as thiopentone do produce very characteristic pictures Broadly speaking the alpha or fast activity disappears in the transition between the second and third plane of stage 3 As anæsthesia deepens there is a general decrease in the beta activity (round about 10 cycles per second) and this is replaced by slow waves having a frequency of 0 5–2 cycles per second

Hewer suggests that by far the most important use is during the surgery of anterior middle and posterior cerebral artery aneurysms Whenever possible a bilateral recording is performed so that the unaffected hemisphere may be used as a control When the blood supply to a hemisphere is occluded at normal temperatures it passes very rapidly through the three phases of activity already described until eventually complete silence supervenes The time taken for this to happen is prolonged if hypothermia is used but the significance of E E G silence is not clear since many cases have been recorded where there has been no E E G activity for 10 minutes or more after occlusion of a main vessel and yet the patient appears to have made a normal recovery with no demonstrable permanent damage In spite of this at the present moment the E E G silence is taken seriously because it is obvious that some change has taken place although its nature is unknown

A further use of this technique is in the tracing of epileptic foci These can be localized to a small area of cortex and the direction of propagation can be traced so that this can act as a guide to the surgeon as to which area of cortex to excise Unfortunately it is frequently found that after the excision of an epileptic area when the electrodes are placed over an adjoining area of cortex which was previously normal the E E G spikes appear to have jumped back into this area It is possible that the real cause of the trouble is somewhere deeper in the brain and that the spike which is recorded from the surface of the cortex is merely an echo of a disturbance which is occurring somewhere else

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Chapter 8

INDIVIDUAL OPERATIONS 2
THE SPINAL CORD

Laminectomy

The prone position

This position is used for the exploration of the spinal canal in cases of compression from extradural lesions or those within the theca whether intramedullary or extramedullary

In this prone position the abdomen must be allowed to hang as freely as possible. Any compression of the abdomen and possibly of the inferior vena cava against the bodies of the lumbar vertebræ, will produce a rise of pressure in the vertebral venous plexus which forms a part of the anastomotic channel for an obstructed vena cava Pearce[1] investigating this found that pressure on the abdomen sufficient to cause vena caval obstruction produced a rise in venous pressure to over 300 mm H_2O in one case He considers that a rise of 30 to 40 mm H_2O is probably large enough to distend the thin walled epidural veins For this reason bolsters have been designed which can be fixed along both sides of the operating table (Fig 51) The patient is turned on to these so that his weight is taken mainly by his anterior superior iliac spines and shoulders (Fig 52) His body is flexed so that the operation site is at the highest level and the table tilted foot down Diaphragmatic movements will be restricted if the abdomen is compressed Coughing and straining and increased tension of the abdominal muscles will also increase the tendency for oozing from the epidural veins For this reason it is the practice of some anæsthetists to give paralysing doses of *d* tubocurarine chloride and then artificially respire the patient so that adequate ventilation and laxity of the abdominal muscles are ensured Personally we are once more in favour of maintaining spontaneous respiration provided that the patient is properly anæsthetized and positioned

In conclusion Hewer mentions that considerable interest has been aroused by the possibility of mapping out areas of the sensory cortex which have been exposed during an operation Parts of the body or peripheral nerves such as the median are stimulated electrically and the potential evoked on the cortex serves as a guide to exact localization when operating on the posterior parts of the frontal lobe

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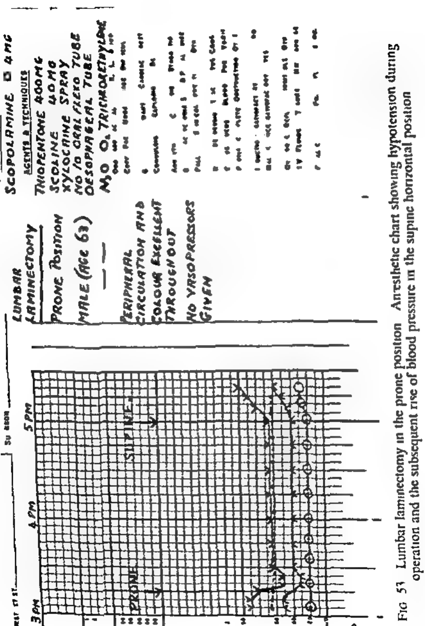

FIG 53 Lumbar laminectomy in the prone position Anæsthetic chart showing hypotension during operation and the subsequent rise of blood pressure in the supine horizontal position

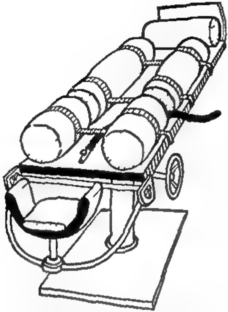

FIG 51 The prone position This shows the bolsters strapped along the sides of the table and the head rest in position for cervical laminectomy

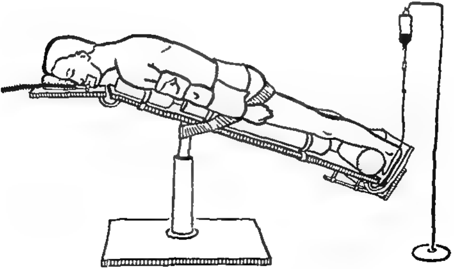

FIG 52 The prone position This shows the patient in position for dorsal laminectomy

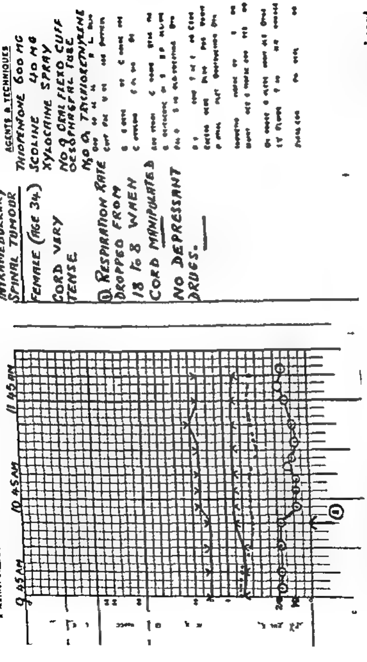

FIG 54 Cervical laminectomy in the prone position Intramedullary tumour and very tense spinal cord Anæsthetic chart to show bradypnœa associated with surgical manipulation of the cord

There is a danger when the prone position is used that stomach contents may be regurgitated even in the well prepared patient For this reason we pass an œsophageal tube when the patient is anæsthetized and before he is turned over As an additional safeguard a cuffed endotracheal tube may be used It is surprising how often stomach content does run out of the œsophageal tube when the patient is turned

Generally the blood pressure falls when the patient is turned into the prone reversed Trendelenburg position and may remain low throughout the operation Usually the peripheral circulation and general condition is otherwise good and vasopressor drugs are not required The blood pressure rises directly the patient is turned into the supine horizontal position (Fig 53)

Spinal tumours

Bleeding may occasionally occur during removal of tumours particularly those arising from the meninges It is essential to anticipate this and to have an intravenous drip running before the patient is turned over otherwise it will be very difficult to insert a needle with the patient prone

Respiratory changes of central origin may occur in cervical spinal tumours when the cord has been severely compressed and there is any rotation during surgery (Fig 54) Respiratory muscle action may be affected by cervical cord lesions and ventilation require assistance not only in the theatre but also later in the wards Tracheostomy may be indicated

Chordotomy

In some cases of intractable pain especially from carcinoma bilateral division of the lateral spinothalamic tracts is the only procedure that will give relief These patients will usually be severely ill and often anæmic They will have been having large doses of analgesic and other drugs for pain relief and require particular care during anæsthesia Secondary deposits may have arisen in bone and make spontaneous fracture possible

These patients are often particularly susceptible to postural hypotension

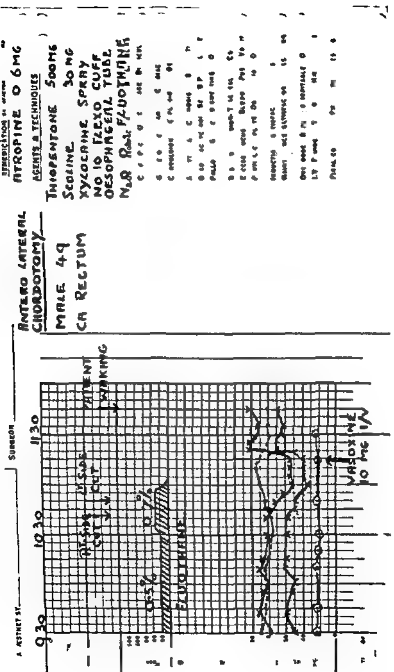

FIG 56 Chordotomy Another typical anæsthetic chart

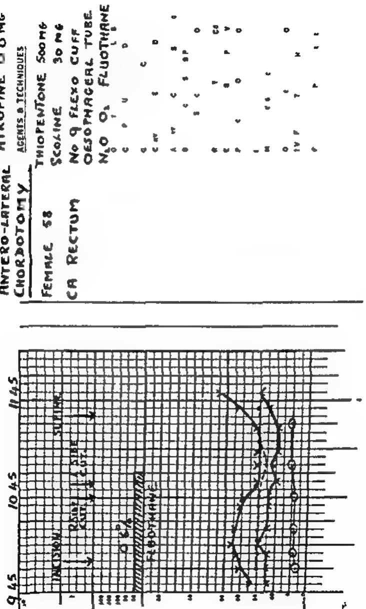

FIG 55 Chordotomy Anæsthetic chart showing a fall in blood pressure associated with division of both antero lateral spinothalamic tracts

Chapter 9

HEAD INJURIES

LEWIN[1] has made a conservative estimate that between 40 000 and 50 000 cases of head injury require in patient treatment in Great Britain every year and points out that with the ready availability of antibiotics and blood transfusion tending to lower the mortality from other injuries head injury now accounts for nearly three-quarters of all fatal road accidents

The role of respiratory insufficiency in the mortality of severe head injuries has been discussed by Maciver and others[2,3,4] It is well established that the first line of attack in any head injury is the establishment and maintenance of a perfect airway Adequate oxygenation must be ensured and respiration assisted if necessary from the time of the accident during transit reception and in the ward This involves the isolation of the lungs from the upper respiratory tract as soon as possible

The physiological principles in the treatment of the unconscious patient have been discussed by Mushin[5] He stresses how readily pulmonary œdema may develop when respiration is obstructed and the dynamics altered across the alveolar membrane The undue fall in intra alveolar pressure at each inspiration tends to draw fluid from the pulmonary capillaries and if in addition there is generalized anoxia the permeability of the alveolar vessels is increased and a vicious circle created Altschule[6] mentions that pulmonary œdema may be caused by an acute cerebral lesion and Andrew suggests that there may be secretion from tracheo bronchial mucous glands of central reflex origin[7] Seymour[8] has found that subarachnoid blood in the posterior fossa of cats may result in mucus secretion in the bronchial tree

Respiratory obstruction which may develop in any unconscious patient is likely to be complicated in the head injury by respiratory depression either from direct injury to the medulla oblongata or pons or secondarily from a raised intracranial pressure causing

During the removal of the protruded disc and retraction of the spinal nerve respiration may be stimulated. Some deepening of the anæsthesia with pethidine or thiopentone may be indicated but *attempts to suppress completely the effects of the surgery must be* resisted otherwise the patient will be unnecessarily depressed when the period of surgical stimulation is passed

Using this anæsthetic technique we have found in a large series of cases that the operation is almost bloodless. Blood transfusion has only been required once in the last ten years and the use of hypotensive agents is quite unnecessary

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carbon dioxide retention decrease the resistance to respiration, facilitate the removal of tracheo bronchial secretions and result in an improved venous return and cardiac output It will allow the head to be raised and thus reduce cerebral venous congestion [7] Lewin[11] has suggested the following indications for tracheostomy in head injury—

1 Deep coma
2 Associated fracture of jaw
3 Combined head and chest injury
4 Pre existing chest disease
5 Associated fracture of femur This because of the immobilization required and difficulty of posturing the patient
6 Cervical cord injury

A short cuffed rubber tracheostomy tube[1] is used if it is necessary to isolate the lungs from the alimentary tract or to apply positive pressure ventilation Matheson[13] and his colleagues have pointed out some of the disadvantages of the cuffed tube namely that fluid can collect above the cuff that there is no alternative airway so that blockage produces complete respiratory obstruction and that the cuff has to be deflated at intervals to avoid pressure necrosis They have found that Durham s metal tube is satisfactory for general use

Tracheo bronchial suction must be performed regularly Soft sterile catheters with angulated tips are used and care taken not to traumatize the mucous membrane by vigorous in and out movements It has been shown that if an angulated bronchoscopy catheter is used this can be guided into the left main bronchus with a reasonable prospect of success [14] provided that the tracheostomy tube is not too long and does not extend towards the right main bronchus close to the carina

Humidification of the atmosphere will discourage crusting from dehydrated secretions In addition Maciver[15] recommends the use of Alevair from a Collinson s inhaler for reducing the viscosity of mucous secretions Occasionally if secretions cannot be removed easily or atelectasis develops bronchoscopy will be required and is a fairly simple manœuvre through the tracheostome

If the tidal volume is insufficient to maintain physiological tensions

mid brain shift and temporal lobe herniation There is a possibility of associated facio maxillary injury and the danger of aspiration of blood C S F and stomach contents In the treatment of the unconscious patient the passage of a stomach tube at the earliest opportunity is essential [9]

There may be additional injury to the chest, abdomen and limbs, which will complicate the picture and require active treatment Clarke[10] has stressed that the presence of a head injury is no reason for not treating associated bleeding, even when this is not likely to be immediately fatal

Respiratory insufficiency leads to anoxia, carbon dioxide accumu lation and a rise in intracranial venous and cerebro spinal fluid pressure Cerebral œdema may already be present from brain injury, and increase Vital brain stem and mid brain structures already shifted by intracranial hæmorrhage may become further distorted by hyperæmia and œdema Internal hydrocephalus will follow aqueduct obstruction and central respiratory disturbance increase with the rising pressure A vicious circle of respiratory inadequacy and rising intracranial pressure is thus established

The airway must be kept clear for 24 hours a day, and Lewin[11] stressing this has reminded us that this may be possible for weeks with good nursing alone This will involve the use of the lateral horizontal head down or semi prone position to encourage seepage of secretions away from the tracheo bronchial tree and lungs It will mean turning the patient from one side to the other every few hours regular physiotherapy and the use of antibiotics Feeding during the period of deep coma will be by nasal tube Nursing problems will also arise from the presence of spasticity of the limbs (see Chapter 11)

In some cases an artificial airway will be required and an endo tracheal tube may have to be passed as an emergency measure to tide a patient over a short period of obstruction or during trans portation In the presence of an active larynx a tube should only be in place for a few hours as laryngeal œdema may develop If coma persists and the airway cannot be maintained by the nursing staff alone then a tracheostomy must be performed This will by pass upper respiratory tract obstruction reduce the dead space and

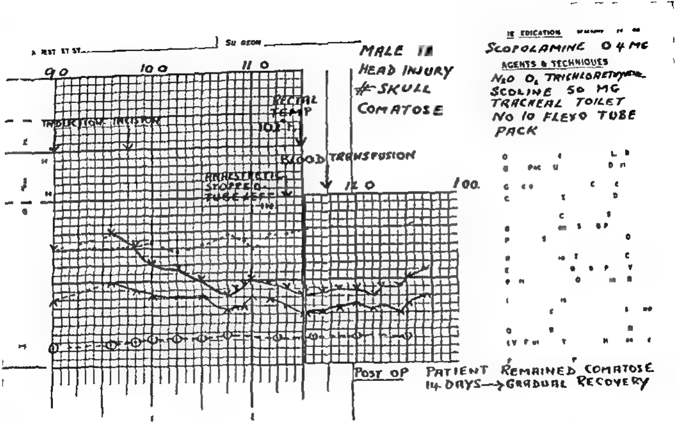

FIG 59 Anaesthetic chart in a case of head injury This chart shows the high pulse rate falling blood pressure and pyrexia that may be associated with head injuries

of oxygen and carbon dioxide in the blood then intermittent positive pressure respiration will be required

In severe head injuries with decerebrate rigidity and a rapidly rising temperature from mid brain shift and damage to the temperature regulating mechanism of the hypothalamus and pons, cooling will be required and dehydration therapy be of value [4] As mentioned previously it is our practice to try and bring the temperature to normal but not to induce hypothermia (Fig 59)

Biochemical upset with high blood and low urine levels of sodium chloride and the development of uræmia may follow cerebral disorders and head injuries [16] Electrolytes must be estimated regularly and particular attention paid to the serum potassium level [1] for the maintenance of a normal electrolyte balance forms a vital part of the treatment [13]

Anæsthesia

Some patients may already be in deep coma before surgery which can be performed with local infiltration of lignocaine hydrochloride Laryngoscopy can be performed and the trachea intubated with a cuffed tube without anæsthesia Suction may be required during larnygoscopy and following intubation for aspiration of blood C S F and stomach contents will often have occurred before admission during transit This underlines the importance of attention to the airway and the avoidance of aspiration right from the moment of injury an ideal that must become reality

In some cases an endotracheal or tracheostomy tube may already be in place and following atropine premedication and tracheo bronchial suction anæsthesia with nitrous oxide oxygen and trichlorethylene is given readily if required

In the less deeply comatose patient either suxamethonium alone or nitrous oxide oxygen trichlorethylene followed by suxamethonium may be required before intubation is possible Thiopentone given to a patient already comatose with disturbed respiratory centre and raised intracranial pressure is dangerous and may be followed by respiratory failure

As in any accident case the possibility of regurgitation during induction must be remembered A stomach tube should already be

Chapter 10

RADIOLOGICAL INVESTIGATIONS

GENERAL anæsthesia for neurosurgical investigations, however trivial these may seem requires all the care and vigilance that is applied to major cases Indeed some of these patients are so desperately ill that the procedures are only performed to confirm a diagnosis

A pre existing raised intracranial pressure will usually be further raised by anæsthesia and the subsequent investigation Unlike cases undergoing craniotomy there will be no relief of pressure from the lifting of the bone and dural flaps, and it may become necessary to perform ventricular drainage or proceed to craniotomy immediately following ventriculography In cases of subarachnoid hæmorrhage intense spasm of the vessels adjacent to aneurysms may exist and these vessels remain hypersensitive to minor stimuli, so that further spasm is readily induced The solutions used in angiography may aggravate existing spasm and result in circulatory disturbances and transient complications such as hemiparesis [1]

The majority of neurosurgical investigations are designed to demonstrate abnormalities in the position shape or size of the ventricular system and subarachnoid space, together with abnormalities of the arterial and venous systems From them may be deduced the position and extent of most intracranial and spinal lesions Not only is accurate siting possible, but some clue as to the nature of the lesion is likely to be found

Air oxygen or opaque solutions are used in the investigations to be considered

Investigations Using Air and Oxygen

1 Ventriculography
2 Pneumoencephalography—
    (a) Lumbar
    (b) Cisternal

in place and suction is applied to this to ensure that the stomach is empty The head end of the table is raised before suxamethonium is given and a cuffed tube passed as soon as possible If any anæsthesia is required during surgery nitrous oxide and oxygen alone will usually suffice An intravenous drip is always set up and blood transfused as required

Following operation coma will often persist initially and care of the airway remains the first consideration

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Fig 60 Normal ventriculogram Brow up position showing filling of anterior part of ventricular system

Fig 61 Normal ventriculogram Brow-down position showing filling of posterior part of ventricular system

Ventriculography

In most units this investigation is performed using local analgesia except in the very young frightened or unduly restless patient, when it is wiser and kinder to use general anæsthesia

The purpose of the investigation is to replace the ventricular C S F with air or oxygen so that on subsequent X ray examination a complete outline of the ventricular system is obtained

Indications for ventriculography These are many and varied but in general the investigation is for the localization of a suspected intracranial space occupying lesion in patients with the symptoms and signs of a raised intracranial pressure

General anæsthesia Premedication is with atropine alone particularly when the intracranial pressure is very high and the level of consciousness altered In the highly nervous patient this will be combined with phenobarbitone given 1½ hours before the investigation Anæsthesia is induced as described in Chapter 3, except that a cuffed flexometallic endotracheal tube is used, and the cuff inflated This will prevent the aspiration of stomach contents that might otherwise occur when the patient is turned into the prone position during the X ray examination When anæsthesia is fully established *and the patient thoroughly settled on the endotracheal tube he is* moved into the theatre The head end of the operating table is raised slightly and the patient is in the supine position with the head partially flexed

Two burr holes are made 1½ in from the mid line in the parieto occipital region The dura is exposed and opened, and an exploring needle is passed through the underlying brain into the lateral ventricle on each side The C S F pressure is measured and the variation with respiratory and cardiac activity recorded Gradually oxygen is passed into the ventricles and fluid withdrawn until as complete a replacement as desirable has been achieved The scalp wounds are then closed in layers

This procedure does not usually produce any major change in the patient s general condition Occasionally temporary decompression will improve a patient who has a very high intracranial pressure At other times alteration of the tumour brain relationship may

may become pale with a rapid pulse of poor volume and shallow respirations She also mentions that vomiting and gasping respirations may indicate a dangerous rise in intracranial pressure requiring ventricular tap

Cisternal This is a variation of the preceding investigation Again the patient is sitting but this time the needle is passed between

FIG 62 Drawing to show a patient in the sitting position for lumbar pneumoencephalography

the posterior arch of the atlas and the occiput through the atlanto-occipital ligament into the cisterna magna Owing to the proximity of the floor of the fourth ventricle and the related structures, absolutely stable anæsthesia is essential A sudden cough when the needle is in position could be disastrous The patient must be watched very closely and any change in the vital functions is reported to the surgeon at once for failure to do this may result in permanent damage

result and be accompanied by a deterioration of his condition, with cardiovascular and respiratory changes

Once it is thought that the ventricles have been filled with oxygen the patient is transferred to the X ray table where a series of views are taken This will involve flexion extension and rotation of the head as well as movement of the body into the lateral and prone positions Adequate precautions must therefore be taken to see that laryngeal and tracheal reflexes are thoroughly suppressed by the use of adequate lignocaine spraying during induction and sufficient depth of anæsthesia Occasionally the use of a small dose of *d* tubocurarine chloride may be valuable in settling the difficult patient Failure to establish stable anæsthesia will inevitably result in coughing and straining and the accompanying rise in intracranial pressure will force a variable quantity of oxygen out of the ventricles and into the subarachnoid space with a consequent loss of definition in the radiographs All metal connections must be clear of the X ray field and the catheter mount is usually directed laterally over the patient s chin It may be necessary to disconnect the anæsthetic tubing from time to time when the patient is repositioned and a swivel endotracheal tube connector has been described[9] for use in these circumstances

Examples of ventriculograms are shown in Figs 60 and 61

Pneumoencephalography

Lumbar When general anæsthesia is required the method used is the same as that already described Respiratory depressant and hypotensive drugs are kept to a minimum as the investigation is begun with the patient in the sitting position (Fig 62)

Lumbar puncture is performed and oxygen replacement of C S F begun The oxygen passes upwards into the fourth ventricle and thence to the other parts of the ventricular system and its progress is kept under X ray control so that the minimum quantity of oxygen necessary to show up the ventricles is used This is usually 20–30 ml The patient is lifted on to the X ray table and films are taken in the horizontal supine and prone positions (Figs 63 and 64)

Coles[3] has observed that small children do not tolerate well the introduction of large quantities of air and has described how they

Indications for pneumoencephalography

1 Investigation of a suspected cerebral tumour unassociated with an obviously raised intracranial pressure

2 Investigation of epilepsy occurring late in life

Pneumoencephalography has the advantage over ventriculography that information relating to the subarachnoid space in the area may be obtained

Contra indications

No patient with a raised intracranial pressure should have pneumo encephalography as there is the danger that medullary coning may result

Investigations Using Radio opaque Solutions

1 Ventriculography
2 Cerebral angiography
3 Spinal myelography
4 Outlining a cerebral abscess

Ventriculography

A radio opaque solution may be injected into the lateral ventricles as described in oxygen ventriculography Local analgesia is quite satisfactory in the majority of cases but a general anæsthetic is occasionally necessary

Two to 3 ml of Myodil are injected into the lateral ventricles and under fluoroscopy the solution is run into the third ventricle and subsequently into the aqueduct and fourth ventricle

Indications for Myodil ventriculography

This is used in cases of internal hydrocephalus where it is desirable to investigate a blockage in the IIIrd ventricle aqueduct or IVth ventricle

Cerebral angiography

Many of the patients submitted for this examination are gravely ill They may have had a recent intracranial hæmorrhage and be

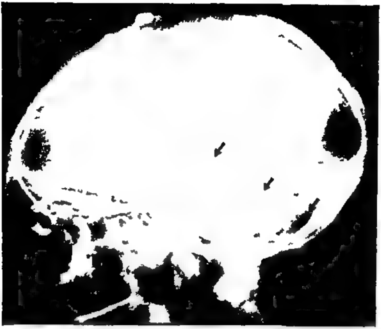

FIG 63 Lumbar pneumoencephalogram (15 ml oxygen) Chin down view showing cisterna magna IV ventricle and aqueduct (Arrowed)

FIG 64 Lumbar pneumoencephalogram Postero anterior view showing normal IV ventricle (Arrowed)

fixation and puncture of the carotid artery is facilitated A certain amount of extravasation of blood is inevitable following angiography This will be aggravated by a patient straining and coughing so that at all times adequate suppression of respiratory reflexes is essential As in all neuroradiological investigations the anæsthetic agents must be non-explosive, the apparatus must not encroach on the surgical or radiological field, the anæsthetist must be ready to co-operate with the radiologist in the positioning of the patient and must ensure that during these movements the fixation of the endo tracheal tube and quality of the airway remain undisturbed The blood pressure pulse and respiration rates are recorded during the investigation

Brown[1] has described two patterns of hypotensive response during this operation The specific reaction was found only in cases of recently ruptured aneurysms or where there had been injury to part of the hypothalamus or basal ganglia, and was thought to be due to vascular spasm from the irritant effect of the dye on hypersensitive vessels A delayed non specific fall of blood pressure occurred in about 9% of all patients subjected to cerebral angiography with Uriodone and was thought to be due to temporary cerebral œdema as a result of damage to the vascular endothelium by the contrast medium Whatever the cause if a sudden serious fall of blood pressure occurs during angiography then the intravenous injection of 3–6 mg of methylamphetamine will be required Hypotension must not be allowed to persist for if this is associated with severe vascular spasm complications such as dysphasia hemiparesis and disordered consciousness may be found post operatively

Stark[4] found a rise in blood pressure of 20 mm Hg or more to be a feature of cerebral angiography under general anæsthesia confined to patients who had had a subarachnoid hæmorrhage

Indications for cerebral angiography

Carotid and less commonly vertebral angiography is carried out for the investigation of spontaneous intracranial hæmorrhage and for the diagnosis of intracranial vascular lesions especially aneurysms and vascular anomalies It is also of value in determining the position of space occupying lesions such as neoplasms hæmatomata and

suffering from the effects of cerebral damage either direct, or from accompanying vascular spasm and cerebral œdema. Respiratory infection may be present if prolonged coma has preceded the investigation

Different neurosurgical units vary in their approach to cerebral angiography so far as anæsthesia is concerned. We, and many others believe that although the patient suffers some discomfort, provided he is able to co operate, there is less risk involved and better pictures are obtained using local analgesia. It is also possible to observe more accurately the patient s neurological and general state during the procedure. If at any time his condition deteriorates the investigation can be stopped

Stark[4] believes that too great a strain is placed on both the patient and operator when the investigation is performed under local analgesia. To diminish the subjective symptoms of flushing heat and retro bulbar pain following injection of the dye some suggest that this should be diluted, although the clarity of the films may suffer. Our radiological colleagues have found that 60% Urografin produces less pain than other media gives better contrast and that less of the dye crosses the blood brain barrier causing cerebral complications

Brown[1] believes that general anæsthesia is safer, not only because the patient is saved emotional stress but also because some degree of vasodilatation will result from it and be of advantage in certain intracranial vascular lesions. He also finds that with abolition of consciousness and depression of reflex responses to painful stimuli it is easier to assess the patient s physical state

Whilst accurate recordings of blood pressure pulse rate and respiration may be facilitated during general anæsthesia other signs such as increasing drowsiness and aphasia cannot be observed. However because of the strain on both patient and surgeon we do not hesitate to use an anæsthetic when we think it is required particularly in the very young frightened or confused patient who cannot be controlled by mild pre operative sedation

General anæsthesia must provide the same good operation conditions that are necessary for major surgery. The sterno mastoid muscles must be relaxed so that accurate palpation and subsequent

fixation and puncture of the carotid artery is facilitated A certain amount of extravasation of blood is inevitable following angio graphy This will be aggravated by a patient straining and coughing so that at all times adequate suppression of respiratory reflexes is essential As in all neuroradiological investigations the anæsthetic agents must be non explosive, the apparatus must not encroach on the surgical or radiological field, the anæsthetist must be ready to co operate with the radiologist in the positioning of the patient and must ensure that during these movements the fixation of the endo tracheal tube and quality of the airway remain undisturbed The blood pressure pulse and respiration rates are recorded during the investigation

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abscesses in the anterior two thirds of the cerebral hemispheres The angiographic appearances may be diagnostic of the particular pathological lesion present

Vertebral angiography is used for demonstrating aneurysms and less often tumours in the posterior fossa

FIG 65 Normal cerebral angiogram showing anterior middle and posterior cerebral arteries

Angiography has the advantage over ventriculography that the intracranial pressure and tumour brain relationship are not disturbed and immediate craniotomy is rarely necessary (Figs 65 66 and 67)

Myelography

This is always performed under local analgesia except in children Myodil is used and no particular anæsthetic problems exist

Cerebral abscess

Thorotrast may be injected into a cerebral abscess cavity to outline its boundaries following aspiration of its contents It is taken up by

FIG 66 Cerebral angiogram showing large supra-clinoid aneurysm arising from the internal carotid artery close to the posterior communicating branch

FIG 67 Cerebral angiogram showing an angioma in the temporal lobe with abnormal vessels and venous drainage

abscesses in the anterior two thirds of the cerebral hemispheres The angiographic appearances may be diagnostic of the particular pathological lesion present

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Chapter 11

PRE OPERATIVE AND POST OPERATIVE CARE NURSING

Craniotomy—General

Pre-operative preparation In cases with a raised intracranial pressure fluids are restricted and magnesium sulphate enemata may be given daily or on alternate days (see Chapter 4) C S F and blood investigations are performed and stored blood is cross-matched for possible transfusion X-rays are taken and electro encephalographic tracings recorded When hypotension or hypo thermia is to be undertaken the blood urea is estimated and E C G tracings obtained

Post operative care These cases are nursed on a sorbo mattress and one pillow is allowed If the blood pressure is satisfactory the head of the bed is raised slightly after 6 hours and this is increased to 45° by the second day Intravenous fluids are continued for up to 12 hours and oral feeding begun if the patient is conscious The vital signs are recorded quarter to half hourly at first then reduced to hourly and on the third day to four hourly Physiotherapy with turning breathing and limb exercises is carried out regularly at four hourly intervals Fluids are restricted to 1500 ml per 24 hours

Aspirin mucilage is prescribed for pyrexia but no other analgesics are given Soluble penicillin 500 000 units is given six hourly and phenobarbitone 64 mg (gr 1) twice daily

Following frontal craniotomy periorbital œdema may occur from the second to the fourth day requiring ice compresses and regular swabbing of the eye with warm saline Lumbar puncture is occasion ally required if the bone flap is riding

Acoustic Neurinomata

Pre-operative preparation These patients are given a high protein diet and their general condition boosted as much as possible as convalescence may be protracted following this operation

the granulation tissue but provided that not more than 1 ml is used there are said to be no dangers from it

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[1] BROWN A E (1955) *Anæsthesia*, **10** 346
[2] DUNCALF D and THOMPSON P W (1956) *Brit J Anæsth* **28**, 450
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required Fluids will be restricted to 1500 ml and a milk diet with high protein and vitamin content given to provide 1100–1200 calories in 24 hours

The importance of maintaining a perfect airway and protecting the lungs from the aspiration of blood, C S F and stomach contents

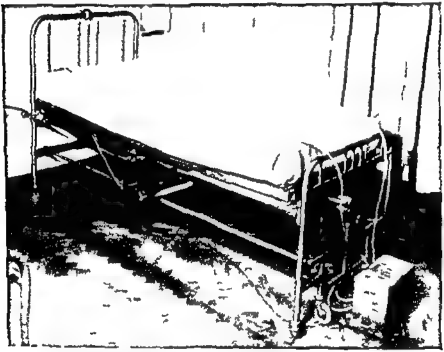

FIG 68 Photograph of the Ripple mattress or alternating pressure point pad for prevention or treatment of decubitus ulcers (Photograph supplied by courtesy of Talley Surgical Instruments Ltd)

has been stressed (see Chapter 9) This will involve the use of the lateral position physiotherapy with regular side to side turning antibiotic therapy possibly some form of artificial airway and the use of suction at frequent intervals to remove secretions

Maciver[1] has discussed the nursing problems and recent advances in the treatment of severe head injuries He details the management of a tracheostomy and the technique of tracheobronchial aspiration underlining the importance of asepsis adequate suction and gentleness

Tarsorrhaphy is performed under local analgesia before craniotomy as the facial nerve may be cut The eyelids remain thus until there is evidence of returned activity of the facial muscles following the operation of facio hypoglossal anastomosis at a later date The eye is subsequently swabbed twice daily with warm normal saline

Post operative care These patients are nursed on a sorbo mattress sitting up and supported with five pillows The neck is extended slightly and the head immobilized as far as possible The vital signs are recorded quarter to half hourly and a rectal thermometer left in position Intravenous fluids are continued for 24 hours and then an attempt made to give oral fluids starting with a teaspoonful of water If there is difficulty in swallowing from damage to the IXth and Xth cranial nerves then the patient is fed via a nasal tube The fluid intake is restricted to 1500 ml per 24 hours

Retention of urine sometimes develops and requires catheterization

Physiotherapy is essential and chest complications are more likely in these cases as the risk of aspiration is greater Occasionally tracheostomy is required

Lumbar puncture every 2–3 days may be required for the first 2 weeks for decompression (Following Torkildsen's operation this is performed daily)

Electrical stimulation of facial muscles begins on the tenth day and a facial splint is worn

Subdural Hæmatomata

Post operative care These patients are allowed one pillow and the foot of the bed is raised on 12 in blocks Fluid intake is unrestricted at over 3000 ml per 24 hours to increase the intra cranial pressure following the evacuation of hæmatoma and consequent decompression The blocks are removed after 48 hours and the patient gradually sat up The use of intrathecal saline following lumbar puncture during operation has been mentioned in Chapter 7

Head Injuries

Head injuries are nursed on a sorbo or Ripple mattress (Fig 68) If they are comatose then intravenous or nasal tube feeding will be

These patients are up and dressed on the fifth day, start back exercises on the seventh day, and leave hospital in three weeks

Laminectomy for Chordotomy and Spinal Tumours

Pre-operative preparation Myelograms are taken in cases of suspected spinal tumour

Post-operative care Following chordotomy the Ripple mattress is used and these cases are nursed flat on their backs with one pillow for 14–18 days, being turned and their backs treated four hourly

Fluids are unrestricted but retention of urine is invariable Women are catheterized intermittently, while men have an indwelling Foley catheter and four hourly irrigations with 1 in 10 000 flavine After 2 weeks carbachol is started six hourly and the patient catheterized for residual urine, then gradually this is stopped Sulphadimidine 1 g six hourly and penicillin 500 000 units six hourly are used

Following chordotomy the large doses of analgesic drugs on which the patient may have depended pre-operatively are gradually reduced

We wish finally to pay a tribute to those who nurse neurosurgical cases Their patience and cheerfulness in dealing with patients who are often unable to help themselves are an example to us all and the undramatic role they play is too easily forgotten

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[1] MACIVER I N (1959) *Nursing Times* 55, 246–339
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Magnesium sulphate enemata will be given daily in the presence of raised intracranial pressure and some surgeons give caffeine and sodium benzoate 500 mg (gr 7[1]) six hourly when the level of consciousness is altered Penicillin 1,000 000 units eight hourly are given with sulphadiazine 1 g four hourly

The possible use of hypertonic intravenous fluids and hypothermia have been mentioned previously (see Chapters 4, 6 and 9)

In spastic conditions the limbs may have to be splinted to prevent flexion contractures and occasionally the patients are nursed in the prone position with the head held in a special rest This latter position may require the use of tracheostomy to ensure the main tenance of a clear airway [2]

Section of Vth Sensory Root

Pre-operative preparation These patients may be frail and poorly nourished, being afraid to eat for fear of pain A diet rich in protein and vitamins is given

A trichlorethylene inhaler may be used pre operatively but no other analgesics are given

Post operative care An eye shield is in place when these patients return from the theatre and this remains in position except when the eye is swabbed twice a day and liquid paraffin eyedrops instilled After a week dust proof glasses are substituted for the shield and these will have to be worn permanently if the ophthalmic fibres have not been spared at operation

Labial herpes occurs quite commonly post operatively and lasts from about the fifth to the tenth day This is treated with spirit externally gentian violet and mouth washes

Protruded Intervertebral Disc Excision

Post operative care An interior sprung mattress is used and the patients nursed in the lateral position being turned over via the prone position four hourly Limb movements and breathing exercises are performed four hourly

Fluids are unrestricted at 3000 ml or more per 24 hours Occa sional difficulty with micturition is treated with carbachol

These patients are up and dressed on the fifth day, start back exercises on the seventh day and leave hospital in three weeks

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